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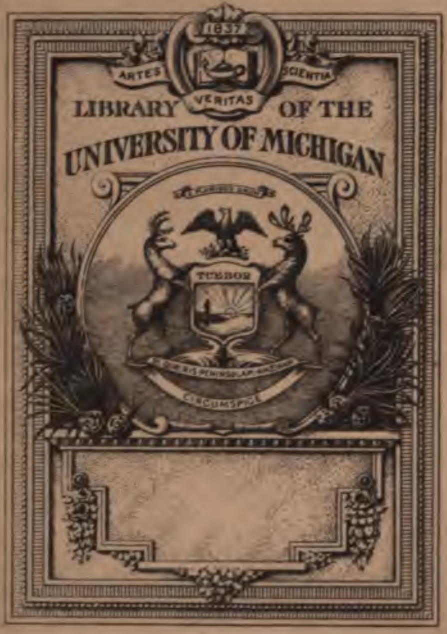

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THE
Deſcription and Uſe
OF THE
GLOBES,
AND THE
ORRERY.

To which is prefix'd,

By Way of INTRODUCTION,

A brief Account of the SOLAR SYSTEM.

By JOSEPH HARRIS,
TEACHER of the MATHEMATICS.

The EIGHTH EDITION.

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THE INTRODUCTION,

CONTAINING

A Brief Account of the SOLAR SYSTEM, and of the FIXED STARS.

SECT. I.

Of the Order and Periods of the Primary Planets revolving about the Sun; and of the Secondary Planets round their reſpective Primaries.

THE Sun is placed in the Midſt of an immenſe Space, wherein ſix opaque ſpherical Bodies revolve about him as their Center. Theſe wandring Globes are called the *Planets*, who, at different Diſtances, and in different Periods, perform their Revolutions from Weſt to Eaſt, in the following Order: *Planets.*

1. ☿ *Mercury* is neareſt to the Sun of all the Planets, and performs its Courſe in

about three Months. 2. ♀ *Venus* in about ſeven Months and a half. 3. ⊕ The *Earth* in a Year. 4. ♂ *Mars* in about two Years. 5. ♃ *Jupiter* in twelve. And laſtly, ♄ *Saturn*, whoſe * *Orbit* includes all the reſt, ſpends almoſt 30 Years in one Revolution round the Sun. The Diſtances of the Planets from the Sun are nearly in the ſame Proportion, as they are repreſented in *Plate* 1. *viz.* Suppoſing the Diſtance of the Earth from the Sun to be divided into 10 equal Parts; that of *Mercury* will be about 4 of theſe Parts; of *Venus* 7; of *Mars* 15; of *Jupiter* 52; and that of *Saturn* 95.

The Orbits of the Planets are not all in the ſame Plane, but variouſly inclined to one another; ſo that ſuppoſing one of them to coincide with the above Scheme, the others will have one half above, and the other half below it; interſecting one another in a Line paſſing through the Sun. The Plane of the Earth's Orbit is called the *Ecliptic*; and this the Aſtronomers make the Standard to which the Planes of the other Orbits are judged to incline. The

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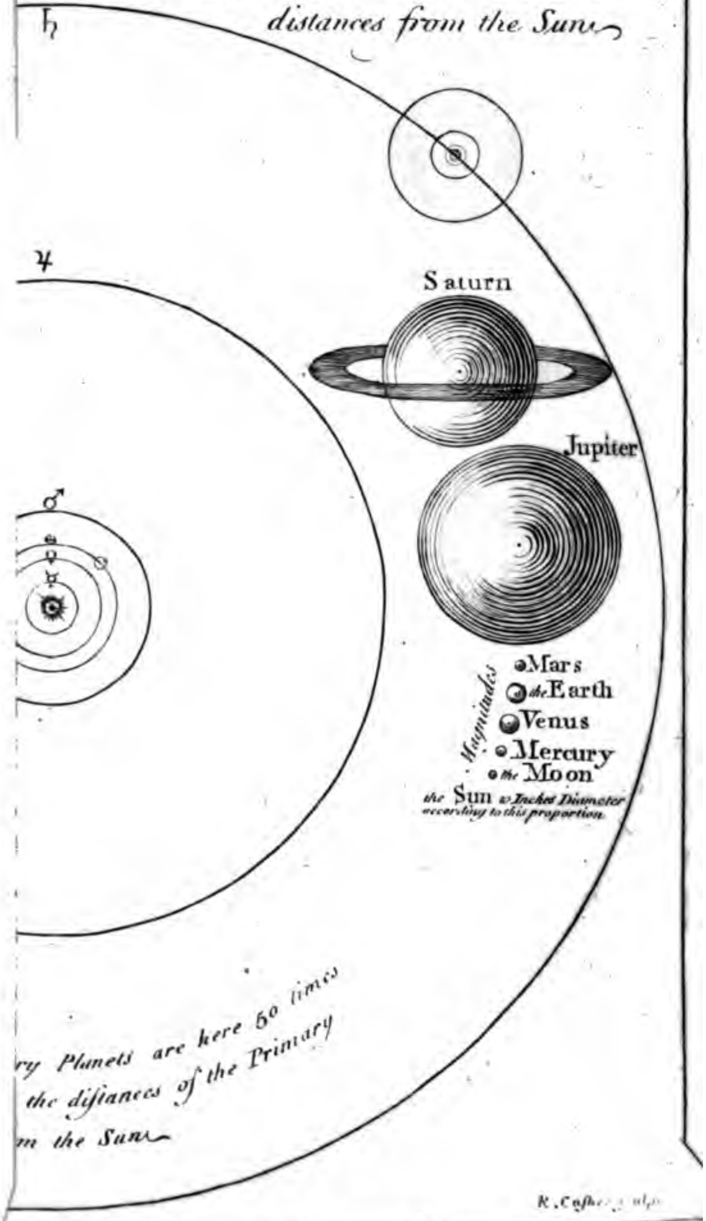
The Characters placed before the Names of the Planets, are for Brevity's Sake commonly made uſe of by Aſtronomers, inſtead of the Words at length, as ♀ for *Venus*, &c.

* By the Orbit of a Planet is commonly underſtood the Tract or Ring, deſcribed by its Center round the Sun, but by the Plane of the Orbit is meant a flat Surface extended every Way thro' the Orbit infinitely.

right

E M Or the Orbits of the Planets
distances from the Sun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Saturn
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ry Planets are here 50 times
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m the Sun
R. Coſhe [illegible]

right Line paſſing thro' the Sun, and the common Interſection of the Plane of the Orbit of any Planet and the Ecliptic, is called the *Line of the Nodes* of that Planet; and the Points themſelves, wherein the Orbit cuts the Ecliptic, are called the *Nodes*. *Nodes.*

The Inclinations of the Orbits of the Planets to the Plane of the Ecliptic, are as follows, *viz.* the Orbit of *Mercury* makes an Angle with it of almoſt 7 Degrees; that of *Venus* ſomething above 3 $\frac{1}{3}$ Degrees; of *Mars*, a litle leſs than 2 Degrees; of *Jupiter*, 1 $\frac{1}{3}$ Degrees; and of *Saturn*, about 2 $\frac{1}{2}$ Degrees. The Orbits of the Planets are not Circles, but Ellipſes or Ovals. What an Ellipſis is, may be eaſily underſtood from the following Deſcription. Imagine two ſmall Pegs fixed upright on any Plane, and ſuppoſe them tied with the Ends of a Thread ſomewhat longer than their Diſtance from one another: Now if a Pin be placed in the Double of the Thread, and turned quite round, (always ſtretching the Thread with the ſame Force) the Curve deſcribed by this Motion is an *Ellipſis*. The two Points where the Pegs ſtood, (about which the Thread was turned) are called the *Foci* of that Ellipſis; and if, without changing the Length of the Thread, we alter the Poſition of the Pegs, we ſhall then have an Ellipſis of a different kind from the former; and the nearer the *Focus's* are together, the

Excentricity.

nearer will the Curve deſcribed be to a Circle; until at laſt the two *Focus's* coincide, and then the Pin in the doubling of the Thread will deſcribe a perfect Circle. The Orbits of all the Planets have the Sun in one of their *Focus's*, and half the Diſtance between the two *Focus's* is called the *Excentricity* of the Orbits. This Excentricity is different in all the Planets, but in moſt of them it is ſo ſmall, that in little Schemes or Inſtruments, made to repreſent the Planetary Orbits, it need not be conſidered.

Primary Planets.

Secondary Planets.

The Six Planets above-mentioned, are called *Primaries*, or *Primary Planets*; but beſides theſe, there are ten other leſſer Planets, which are called *Secondaries*, *Moons*, or *Satellites*. Theſe Moons always accompany their reſpective Primaries, and perform their Revolutions round them, whilſt both together are alſo carried round the Sun. Of the Six Primary Planets, there are but three, as far as Obſervation can aſſure us, that have theſe Attendants, *viz.* the *Earth*, *Jupiter*, and *Saturn.*

The Earth is attended by the *Moon*, who performs her Revolution in about 27$\frac{1}{3}$ Days, at the Diſtance of about 30 Diameters of the Earth from it; and once a Year is carried round the Sun along with the Earth.

Jupiter's four Moons.

Jupiter has four *Moons*, or *Satellites*; the *firſt*, or innermoſt, performs its Revolution in about one Day and 18 $\frac{1}{2}$ Hours, at the

Diſtance of $5\frac{2}{3}$ Semidiameters of *Jupiter* from his Center; the *ſecond* revolves about *Jupiter* in 3 Days and 13 Hours, at the Diſtance of 9 of his Semidiameters; the *third* in 7 Days and 4 Hours, at the Diſtance of $14\frac{1}{3}$ Semidiameters; the *fourth* and *outermoſt* performs its Courſe in the Space of 16 Days 17 Hours, and is diſtant from *Jupiter*'s Center, $25\frac{1}{3}$ of his Semidiameters.

Saturn has five Moons.

Saturn has no leſs than five *Satellites*; the *firſt*, or innermoſt, revolves about him in 1 Day and 21 Hours, at the Diſtance of $4\frac{3}{8}$ Semidiameters of ♄ from his Center; the *ſecond* compleats his Period in $2\frac{3}{4}$ Days at the Diſtance of $5\frac{3}{5}$ of his Semidiameters; the *third*, in about $4\frac{1}{2}$ Days, at the Diſtance of 8 Semidiameters; the *fourth*, performs its Courſe in about 16 Days, at the Diſtance of 18 Semidiameters; the *fifth* and outermoſt takes $79\frac{1}{3}$ Days to finiſh his Courſe, and is 54 Semidiameters of *Saturn* diſtant from his Center. The Satellites, as well as the Primaries, perform their Revolutions from *Weſt* to *Eaſt*: The Planes of the Orbits of the Satellites of the ſame Planet are variouſly inclined to one another, and conſequently are inclined to the Plane of the Orbit of their Primary.

Saturn's Ring.

Beſides theſe Attendants, *Saturn* is encompaſſed with a thin plain Ring, that does no where touch his Body: The Diameter of this Ring is to the Diameter of *Saturn* as 9 to 4; and the void Space between the Ring and the Body of *Saturn* is equal to the Breadth of the Ring itſelf; ſo that in ſome Situations the Heavens may be ſeen between the Ring and his Body. This ſurprizing Phænomenon of *Saturn*'s Ring is a modern Diſcovery; neither were the Satellites of *Jupiter* and *Saturn* known to the Ancients. The *Jovial* Planets were firſt diſcovered by the famous *Italian* Philoſopher *Galilæus*, by a Teleſcope which he firſt invented; and the celebrated *Caſſini*, the *French* King's Aſtronomer, was the firſt that ſaw all the *Satellites* of *Saturn*; which, by Reaſon of their great Diſtances from the Sun, and the Smallneſs of their own Bodies, cannot be ſeen by us, but by the Help of very good Glaſſes.

Annual Motion. The Motion of the primary Planets round the Sun (as alſo of the Satellites round their reſpective Primaries) is called their *Annual Motion*; becauſe they have one Year or Alteration of Seaſons compleat in one of theſe Revolutions. Beſides this Annual Motion, four of the Planets, *viz. Venus*, the *Earth*, *Mars*, and *Jupiter* revolve about their own *Axis*, from *Weſt* to *Eaſt*; and this is called their *Diurnal Motion*. *Diurnal Motion* For by this Rotation each Point of their Surfaces is carried ſucceſſively towards or from the Sun, who always illuminates the Hemiſphere which is next to him, the other remaining obſcure; and while any Place is in the Hemiſphere illuminated by the Sun, it is *Day*, but when it is carried to the obſcure Hemiſphere, it becomes *Night*; and ſo continues, until by this Rotation the ſaid Place is again enlightened by the Sun.

Diurnal Motion of the ⊕, ♀, ♂ and ♃.

The *Earth* performs its Revolution round its Axis in 23 Hours 56 Minutes; * *Venus* in 24 Days 8 Hours; *Mars* in 24 Hours and 40 Minutes; and *Jupiter* moves round his own Axis in 9 Hours and 56 Minutes. The Sun alſo is found to turn round his Axis from Weſt to Eaſt in 27 Days: And the Moon which is neareſt to us of all the Planets, revolves about her Axis in a Month, or in the ſame Space of Time that ſhe turns round the Earth; ſo that the *Lunarians* have but 1 Day throughout the Year.

☉ and ☽ likewiſe turn round their Axes.

The Planets are Opaque and Globular.

I. The Planets are all *Opaque* Bodies, having no Light but what they borrow from the Sun: for that Side of them which is next towards the Sun, has always been obſerved to be illuminated, in what Poſition ſoever they be; but the oppoſite Side, which the Solar Rays do not reach, remains dark and obſcure; whence it is evident that they have no Light but what proceeds from the Sun; for if they had, all Parts of them would be lucid without any Darkneſs or Shadow. The Planets are likewiſe proved to be *Globular*; becauſe, let what Part ſoever of them be turned towards the Sun, its Boundary, or the Line ſeparating that Part from the Oppoſite, always appears to be Circular; which could not happen if they were not Globular.

---

* *N. B.* According to *Biachini*'s Obſervations, *Venus*'s Axis inclines 75 Degrees from the Perpendicular to the Plane, the Ecliptic (which is 51 ½ Deg. more than the Axis of our Earth) her Tropics are only 15 Deg. from her Poles, and her Polar Circles at the ſame Diſtance from her *Equator*; ſo that the Sun's greateſt Declination on each Side of her *Equator* is 75 Deg. by which ſhe muſt undergo a much greater Variety of Seaſons than we do on our Earth.

The Planets turn round the Sun.

II. That the Earth is placed betwixt the Orbs of *Mars* and *Venus*, and that ☿, ♀, ♂, ♃, and ♄, do all turn round the Sun, is proved from Obſervations as follow:

1. Whenever *Venus* is in Conjunction with the Sun, that is, when ſhe is in the ſame Direction from the Earth, or towards the ſame Part of the Heavens the Sun is in; ſhe either appears with a bright and round Face like a Full Moon, or elſe diſappears: Or if ſhe is viſible, ſhe appears horned like a new Moon; which Phænomena could never happen if ♀ did not turn round the Sun, and was not betwixt him and the Earth: For ſince all the Planets borrow their Light from the Sun, it is neceſſary that ♀'s lucid Face ſhould be towards the Sun; and when ſhe appears fully illuminated, ſhe ſhews the ſame Face to the Sun and Earth; and at that Time ſhe muſt be above or beyond the Sun; for in no other Poſition could her illuminated Face be ſeen from the Earth. Farther, when ſhe diſappears, or,

if viſible, appears horned; that Face of her's which is towards the Sun is either wholly turned from the Earth, or only a ſmall Part of it can be ſeen by the Earth; and in this Caſe ſhe muſt of Neceſſity be betwixt us and the Sun. Let S be the *Sun*, T the *Earth*, and V *Venus*, having the ſame Face preſented both towards the *Sun* and *Earth*; here it is plain that the Sun is betwixt us and *Venus*, and therefore we muſt either place *Venus* in an Orbit round the Sun, and likewiſe betwixt him and us, as in *Fig.* 1. or elſe we muſt make the Sun to move round the Earth in an Orbit within that of *Venus*, as in *Fig.* 2. Again, after *Venus* diſappears, or becomes horned, at her * ☌ with the ☉, ſhe then muſt be betwixt us and the Sun, and muſt move either in an Orbit round the Sun, and betwixt us and him, as in *Fig.* 1. or elſe round the Earth, and betwixt us and the Sun, as in *Fig.* 2. But *Venus* cannot move ſometimes within the Sun's Orbit, and ſometimes without it, as we muſt ſuppoſe if ſhe moves round the Earth; therefore it is plain that her Motion is round the Sun.

Plate 2. *Fig.* 1, 2.

Beſides the foregoing, there is another Argument to prove that *Venus* turns round the Sun in an Orbit that is within the Earth's, becauſe ſhe is always obſerved to keep near the Sun, and in the ſame Quarter of the Heavens that he is in, never receding from him more than about $\frac{1}{8}$ of a whole Circle; and therefore ſhe can never come in Oppoſition to him; which would neceſſarily happen, did ſhe perform her Courſe round the Earth either in a longer or ſhorter Time than a Year. And this is the Reaſon why *Venus* is never to be ſeen near Midnight, but always either in the Morning or Evening, and at moſt not above three or four Hours before Sun-riſing or after Sun-ſetting. From the Time of ♀'s ſuperior Conjunction (or when ſhe is above the Sun) ſhe is more Eaſterly than the Sun, and therefore ſets later, and is ſeen after Sun-ſetting; and then ſhe is commonly call'd the *Evening Star*. But from the Time of her inferior Conjunction, till ſhe comes again to the ſuperior, ſhe then appears more Weſterly than the Sun, and is only to be ſeen in the Morning before Sun-riſing, and is then called the *Morning Star*.

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* ☌ is a Mark commonly uſed for Conjunction: thus ☌ with the ☉, is to be read Conjunction with the Sun.

Why *Venus* is always either our Morning or Evening Stars,

After the ſame Manner we prove that *Mercury* turns round the Sun, for he always keeps in the Sun's Neighbourhood, and never recedes from him ſo far as *Venus* does; and therefore the Orbit of ☿ muſt lie within that of ♀; and on the Account of his Nearneſs to the Sun, he can ſeldom be ſeen without a Teleſcope.

The Orbit of *Mars* includes the Earth's.

Mars is obſerved to come in Oppoſition, and likewiſe to have all other Aſpects with the Sun; he always preſerves a round, full, and bright Face, except when he is near his Quadrate Aſpect, when he appears ſomewhat gibbous, like the Moon three or four Days before or after the full: Therefore the Orbit of ♂ muſt include the Earth within it, and alſo the Sun; for if he was betwixt the Sun and us at the Time of his inferior Conjunction, he would either quite diſappear, or appear horned, as *Venus* and the Moon do in that Poſition. Let S be the *Sun*, T the *Earth*, and A P *Mars*, both in his Conjunction and Oppoſition to the Sun, Fig. 3. and in both Poſitions full; and B C *Mars* at his Quadratures, when he appears ſomewhat gibbous from the Earth at T. 'Tis plain hence, that the Orbit of *Mars* does include the Earth, otherwiſe he could not come in Oppoſition to the Sun; and that it likewiſe includes the Sun, elſe he could not appear full at his Conjunction.

Mars, when he is in Oppoſition to the Sun, looks almoſt ſeven Times larger in Diameter than when he is in conjunction with him, and therefore muſt needs be almoſt ſeven times nearer to us in one Poſition than in the other; for the apparent Magnitudes of far diſtant Objects increaſe or decreaſe in Proportion to their Diſtances from us. But *Mars* keeps always nearly at the ſame Diſtance from the Sun; therefore it is plain that it is not the Earth but the Sun that is the Center of his Motion.

It is proved in the ſame Way, that *Jupiter* and *Saturn* have both the Sun and the Earth within their Orbits, and that the Sun, and not the Earth is the Center of their Motions; altho' the Diſproportion of the Diſtances from the Earth is not ſo great in *Jupiter* as it is in *Mars*, nor ſo great in *Saturn* as it is in *Jupiter*, by Reaſon that they are at a much greater Diſtance from the Sun.

Inferior and *Superior Planets.*

We have now ſhewn that all the Planets turn round the Sun, and that *Mercury* and *Venus* are included between him and the Earth, whence they are called the *Inferior Planets*, and that the Earth is placed between the Orbits of *Mars* and *Venus*, and therefore included within the Orbits of *Mars*, *Jupiter* and *Saturn*, whence they are called the *Superior Planets:* And ſince the Earth is in the Midde of theſe moveable Bodies, and is of the ſame Nature with them, we may conclude that ſhe has the ſame Sort of Motions; but that ſhe turns round the Sun is proved thus:

The Earth does not ſtand ſtill, but turns round the Sun.

All the Planets ſeen from the Earth appear to move very unequally, as ſometimes to go faſter, at other times ſlower; ſometimes to go backwards, and ſometimes to be ſtationary, or not to move at all; which could not happen if the Earth ſtood ſtill. *Fig.* 4. Let S be the Sun, T the Earth, the great Circle A B C D the Orbit of *Mars*, and the Numbers 1, 2, 3, *&c.* its equable Motion round the Sun; the correſpondent Numbers 1, 2, 3, *&c.* in the Circle *a*, *b*, *c*, *d*, the Motion of *Mars*, as it would be ſeen from the Earth. It is plain from this Figure, that if the Earth ſtood ſtill, the Motion of *Mars* will be always progreſſive, (tho' ſometimes very unequal;) but ſince Obſervations prove the contrary, it neceſſarily follows, that the Earth turns round the Sun.

The Annual and Diurnal Motions of the Planets how computed

The annual Periods of the Planets round the Sun are determined by carefully obſerving the Length of Time ſince their Departure from a certain Point in the Heavens, (or from a Fixed Star) until they arrive to the ſame again. By theſe Sorts of Obſervations the Antients determined the periodical Revolutions of the Planets round the Sun, and were ſo exact in their Computations, as to be capable of predicting Eclipſes of the Sun and Moon. But ſince the Invention of Teleſcopes, Aſtronomical Obſervations are made with greater Accuracy, and of Conſequence our Tables are far more perfect than thoſe of the Ancients. And in order to be as exact as poſſible, Aſtronomers compare Obſervations made at a great Diſtance of Time from one another, including ſeveral Periods; by which Means, the Error that might be in the whole is in each Period ſubdivided into ſuch little Parts as to be very inconſiderable. Thus the mean Length of a Solar Year is known even to Seconds.

The Diurnal Rotation of the Planets round their Axis, was diſcovered by certain Spots which appear on the Surfaces. Theſe Spots appear firſt in the Margin of the Planets Diſks, (or the Edge of their Surfaces) and ſeem by Degrees to creep towards their Middle, and ſo on, going ſtill forward, till they come to the oppoſite Side or Edge of the Diſk, where they ſet or diſappear; and after they have been hid for the ſame Space of Time, that they were viſible, they again appear to riſe in or near the ſame Place, as they did at firſt, then to creep on progreſſively, taking the ſame Courſe as they did before. Theſe Spots have been obſerved on the Surfaces of the *Sun*, *Venus*, *Mars*, and *Jupiter*; by which Means it has been found that theſe Bodies turn round their own Axis in the Times before-mentioned. It is very probable that *Mercury* and *Saturn* have likewiſe a Motion round their Axis, that all the Parts of their Surface may alternately enjoy the Light and Heat of the Sun, and receive ſuch Changes as are proper and convenient for their Nature. But by Reaſon of the Nearneſs of ☿ to the Sun, and ♄'s immenſe Diſtance from him, no Obſervations have hitherto been made whereby their Spots, (if they have any) could be diſcovered, and therefore their diurnal Motions could not be determined. The diurnal Motion of the Earth is computed from the apparent Revolution of the Heavens, and of all the Stars round it, in the Space of a natural Day. The Solar Spots do not always remain the ſame, but ſometimes old ones vaniſh, and afterwards others ſucceed in their Room; ſometimes ſeveral ſmall ones gather together and make one large Spot, and ſometimes a large Spot is ſeen to be divided into many ſmall ones. But, notwithſtanding theſe Changes, they all turn round with the Sun in the ſame Time.

How the Relative Diſtances of the Planets from the Sun are determined.

The relative Diſtances of the Planets from the Sun, and likewiſe from each other, are determined by the following Methods: Firſt, the Diſtances of the two inferior Planets ☿ and ♀ from the Sun, in Reſpect of the Earth's Diſtance from him, is had by obſerving their greateſt Elongation from the Sun as they are ſeen from the Earth.

Fig. 5. Elongation.

The greateſt *Elongation* of *Venus* is found by Obſervation to be about 48 Degrees, which is the Angle S T ♀; whence, by the known Rules of Trigonometry, the Proportion of S ♀, the mean Diſtance of *Venus* from the Sun to S T, the mean Diſtance of the Earth from him, may be eaſily found. After the ſame Manner, in the right-angled Triangle S T ☿, may be found the Diſtance S ☿ of *Mercury* from the Sun. And if the mean Diſtance of the Earth from the Sun S T be made 1000, the mean Diſtance of *Venus* S ♀ from the Sun will be 723;

and of *Mercury* S ☿ 387: And if the Planets moved round the Sun in Circles, having him for their Center, the Diſtances here found would be always their true Diſtances: but as they move in Ellipſes, their Diſtances from the Sun will be ſometimes greater, and ſometimes leſs. Their *Excentricities* are computed to be as follows, *viz.*

Excent. of	*Mercury*	80	of the Parts above-mentioned.
	Venus	5	
	Earth	169	

Fig. 6.

Heliocentric and *Geocentric Places*, what.

The Diſtances of the ſuperior Planets, *viz.* ♂, ♃, and ♄, are found by comparing their true Places, as they are ſeen from the Sun, with their apparent Places, as they are ſeen from the Earth. Let S be the Sun, the Circle ABC the Earth's Orbit, AG a Line touching the Earth's Orbit, in which we'll ſuppoſe the ſuperior Planets are ſeen from the Earth in the Points of their Orbits ♂, ♃, ♄; and let DEFGH be a Portion of a great Circle in the Heavens, at an infinite Diſtance: Then the Place of *Mars* ſeen from the Sun is D, which is called his true or *Heliocentric Place*; but from the Earth he'll be ſeen in G, which is called his apparent or *Geocentric Place.* So likewiſe *Jupiter* and *Saturn* will be ſeen from the Sun in the Points E and F, their Heliocentric Places; but a Spectator from the Earth will ſee them in the Point of the Heavens G, which is their Geocentric Place.

The Arches DG, EG, FG, the Differences between the true and apparent Places of the ſuperior Planets, are called the *Parallaxes* of the Earth's annual Orb, as ſeen from theſe Planets. If thro' the Sun we draw S H parallel to A G, the Angles A ♂ S, A ♃ S, A ♄ S, will be reſpectively equal to the Angles D S H, E S H, and F S H; and the Angle A G S is equal to the Angle G S H, whoſe Meaſure is the Arch G H; which therefore will be the Meaſure of the Angle A G S, the Angle under which the Semidiameter A S of the Earth's Orbit, is ſeen from the Starry Heavens. But this Semidiameter is nothing in reſpect of the immenſe Diſtance of the Heavens or Fixed Stars; for from thence it would appear under no ſenſible Angle, but look like a Point. And therefore in the Heavens the Angle G S H, or the Arch G H vaniſhes; and the Points G and H coincide; and the Arches DH, EH, FH, may be conſidered as being of the ſame Bigneſs with the Arches D G, E G, and F G, which are the Meaſures of the Angles A ♂ S, A ♃ S, A ♄ S; which Angles are nearly the greateſt Elongation of the Earth from the Sun, if the Earth be obſerved from the reſpective Planets, when the Line G ♄ ♃ ♂ A, touches the Earths Orbit in A. The nearer any of the ſuperior Planets is to the Sun, the greater is the Parallax of the Annual Orb, or the Angle under which the Semidiameter of the Earth's Orbit is ſeen from that Planet. In *Mars* the Angle A ♂ S (which is the viſible Elongation of the Earth ſeen from *Mars*, or the Parallax of the Annual Orb ſeen from that Planet) is about 42 Degrees, and therefore the Earth is always to the Inhabitants of *Mars* either their Morning or Evening Star, and is never ſeen by them ſo far diſtant from the Sun as we ſee *Venus*. The greateſt Elongation of the Earth ſeen from *Jupiter*, being nearly equal to the Angle A ♃ S, is about 11 Degrees. In *Saturn* the Angle A ♄ S is but 6 Degrees, which is not much above $\frac{1}{4}$ Part of the greateſt Elongation we obſerve in *Mercury*. And ſince *Mercury* is ſo rarely ſeen by us, probably the Aſtronomers of *Saturn* (except they have better Opticks than we have) have not yet diſcovered, that there is ſuch a Body as our Earth in the Univerſe.

The Parallax of the Annual Orb, or the greateſt Elongation of the Earth's Orbit ſeen from any of the ſuperior Planets, being given; the Diſtance of that Planet from the Sun, in reſpect of the Earth's Diſtance from him, may be found by the ſame Methods as the Diſtances of the inferior Planets were. Thus, to find the Diſtance of *Mars* from the Sun, it will be as the Sine of the Angle S ♂ A is to the *Radius*, ſo is the Diſtance A S (the Diſtance of the Earth from the Sun) to S♂, the Diſtance from the Sun to *Mars.* After the ſame Manner the Diſtances of *Jupiter* and *Saturn* are alſo found. The mean Diſtance of the Earth from the Sun being made a 1000, the mean Diſtances of the ſuperior Planets from the Sun are, *viz.* the mean Diſtance from the Sun of

$$\left\{\begin{array}{l}\text{♂ } 1524\\ \text{♃ } 5201\\ \text{♄ } 9538\end{array}\right\}\text{and the Excentricity}\left\{\begin{array}{l}141\\ 250\\ 547\end{array}\right\}$$

To which, if you add or ſubtract their mean Diſtances, we ſhall have the greateſt or leaſt Diſtances of thoſe Planets from the Sun.

There are other Methods by which the relative Diſtances of the Planets might be found; but that which hath been here illuſtrated, is ſufficient to evince the Certainty of that Problem.

How the abſolute Diſtances of the Planets from the Sun are computed.

Hitherto we have only conſidered the Diſtances of the Planets in relation to one another, without determining them by any known Meaſure; but in order to find their abſolute Diſtances in ſome determinate Meaſure, there muſt be ſomething given, whoſe Meaſure is known. Now the Circumference of the Earth is divided into 360 Degrees, and each of theſe Degrees into 60 Geographical Miles, ſo that the whole Circumference contains 21600; and by the known Proportion for finding the Diameter of a

Circle from its Circumference, the Earth's Diameter will be found to be 6872 Miles, and its Semidiameter 3436 Miles. The Parallax of the Earth's Semidiameter, or the Angle under which it is ſeen from a certain Planet, may be found by comparing the true Place of the Planet, as it would be ſeen from the Center of the Earth, (which is known by Computation) with its apparent Place, as it is ſeen from ſome Point on the Earth's Surface. Let CZA be the Earth, ZC its Semidiameter, ⊕ ſome Planet, and BHT an Arch of a great Circle in the Heavens, at an infinite Diſtance. Now the Planet ⊕ will appear from the Earth's Center C, in the Point of the Heavens H; but a Spectator from the Point Z upon the Earth's Surface, will ſee the ſame Object ⊕ in the Point of the Heavens B; and the Arch BH the Difference, is equal to the Angle B⊕H=Z⊕C, the *Parallax*; which being known, the Side C ⊕ the Diſtance of the Planet from the Center of the Earth, at that Time, may be eaſily found. Now if this Diſtance of the Planet from the Earth be determined, when the Centers of the Sun, the ſaid Planet, and of the Earth, are in the ſame right Line, we have the abſolute Diſtance of the Planet's Orbit from the Earth's in known Meaſure; then it will be, as the relative Diſtance betwixt the Earth's Orbit and that of the Planet is to the relative Diſtance of the ſaid Planet from

Parallax of the *Earth's Semidiameter.*

Fig. 7.

from the Sun; ſo is the Diſtance of the Planet's Orbit from the Earth's in known Meaſure to the Diſtance of the ſaid Planet from the Sun in the ſame Meaſure: Which being known, the Diſtance of all the other Planets from the Sun may be found. For, it will be, as the relative Diſtance of any Planet from the Sun, is to its Diſtance from him in a known Meaſure; ſo is the relative Diſtance of any other Planet from him, to its Diſtance in the ſame Meaſure. This may be done by finding the Diſtance of the Planet *Mars*, when he is in Oppoſition to the Sun, after the ſame Manner as we find the Diſtance of a Tree, or the like, by two Stations.

Let ♂ be *Mars*, D the Point on the Earth's Surperficies, where *Mars* is vertical when he is in Oppoſition to the Sun, which may be exactly enough found by Calculation, at which Time let an Obſerver, at the Point Z (whoſe Situation from D muſt be known) take the Altitude of *Mars*, whoſe Complement will be the Angle ♂ ZR; then in the Triangle ♂ ZC will be given the Angle Z♂C, the Angle C (whoſe Meaſure is the Arch D Z) and conſequently the Angle Z ♂ C the Parallax, and alſo the Side Z C the Semidiameter of the Earth; by which we may find C ♂ the Diſtance of *Mars* from the Earth. The extreme Nicety required in this Obſervation, makes it very difficult to determine the exact Diſtances of the Planets from the Sun; but the celebrated Dr. *Halley* has, in the Philoſophical Tranſactions, ſhewed us a more certain Method for finding the Diſtances of the Planets; which is by obſerving the Tranſit of *Venus* over the Sun.

How the Magnitudes of the Planets are determin'd.

The Eye judgeth of the Magnitudes of far diſtant Objects, according to the Quantities of the Angles under which they are ſeen (which are called their apparent Magnitudes;) and theſe Angles appear greater or leſs in a certain Proportion to their Diſtances. Wherefore the Diſtances of the Planets from the Earth, and their apparent Diameters being given, their true Diameters (and from thence their Magnitudes) may be found. How the Diſtances of the Planets may be found has been already ſhewn; their apparent Diameters are found by a Teleſcope, having a Machine fix'd to it for meaſuring Angles, called a Micrometer. Let B D, or the Angle B A D, be the apparent Diameter of any Planet, and AB, or AD, (which by reaſon of the great Diſtances of the Planets in reſpect of their Magnitudes) may be conſidered as being the Diſtance of the ſaid Planet from the Obſerver. Now in the Triangle A B D, having the Sides A B, A D, given, and the Angle A, we have alſo the other Angles B and D, (becauſe the Sides A B, A D, are equal) whence the Side B D the

Fig. 8.

the Diameter of the Planet may be eaſily found by Trigonometry.

From hence it appears, that the ſame Body at different Diſtances, will ſeem to have very different Magnitudes: Thus the Diameter B D will appear from the Point E, to be twice as large as from the Point A. It alſo follows, that a ſmall Body, when at no great Diſtance from us, may appear to be equal, or even to exceed another at a great Diſtance, tho' immenſely bigger. Thus *b d* appears under the ſame Angle, and conſequently of the ſame Bigneſs from the Point A, that the Line B D doth, tho' one vaſtly exceeds the other. And this is the Reaſon, why the Moon, which is much leſs than any of the Planets, appears to us vaſtly bigger than either of them, and even to equal the Sun himſelf, which is many thouſand Times greater in Magnitude.

Why the Moon appears bigger than any of the Planets.

The Diſtances of the Planets, and Periods round the Sun, their Diameters and Velocities round their own Axis, according to modern Computations, are as follow:

		Y. D. H.	Diſtance in Miles.
Saturn	Revolves about the Sun in the Space of	29:167:22	777.000.000
Jupiter		11:314:12	424.000.000
Mars		1:321:23	123.000.000
Earth		0:365: 6	81.000.000
Venus		0:224:16	59.060.000
Mercury		0: 87:23	32.000.000

		D.H.M.	
Moon	Round the Earth.	27:7:43	240:000

	Periods round their own Axis D. H. M.	Diameters in Miles.
Sun	25 : 6 : 0	763.000
Saturn	. . . .	61.000
Jupiter	0 : 9 : 56	81.000
Mars	1 : 0 : 40	4.440
Earth	0 : 23 : 56	7.970
Venus	24 : 8 : 0	7.900
Mercury	. . . .	4.240
Moon	27 : 7 : 43	2.170

The Cauſe of *Eclipſes* and *Phaſes* of the Moon, and ſome other Phænomena not here explained, ſhall be ſhewed when we come to give a Deſcription of the *Orrery*.

Beſides the Planets already mentioned, there are other great Bodies that ſometimes viſit our Syſtem, which are a Sort of Temporary Planets; for they come and abide with

Pa

for awhile, and afterwards with-
om us, for a certain Space of Time,
hich they again return. Theſe wan-
Bodies are called *Comets*.

Of Comets.

Motion of Comets in the Heavens,
ıg to the beſt Obſervations hitherto
ſeem to be regulated by the ſame
ble Law that rules the Planets; for
bits are Elliptical, like thoſe of the
but vaſtly narrower, or more Ex-
Yet they have not all the ſame
on with the Planets, who move from
o Eaſt, for ſome of the Comets
rom Eaſt to Weſt; and their Orbits
ifferent Inclinations to the Earth's
ſome inclining Northwardly, others
wardly, much more than any of the
tary Orbits do.

tho' both the Comets and the Planets
in Elliptic Orbits, yet their Motions
to be vaſtly different: For the Excen-
ies of the Planets Orbits are ſo ſmall,
they differ but little from Circles;
the Excentricities of the Comets are
very great, that the Motions of ſome of
m ſeem to be almoſt in right Lines,
ding directly towards the Sun.

Now, ſince the Orbits of the Comets are
extremely Excentric, their Motions,
hen they are in their *Perihelia*, or neareſt
iſtance from the Sun, muſt be much ſwif-
r than when they are in their *Aphelia*, or
artheſt Diſtance from him; which is the
Reaſon

Reaſon why the Comets make ſo ſhort a Stay in our Syſtem; and when they diſappear are ſo long in returning.

The Figures of the Comets are obſerved to be very different; ſome of them ſend forth ſmall Beams like Hair every Way round them; others are ſeen with a long fiery Tail, which is always oppoſite to the Sun. Their Magnitudes are alſo very different, but in what Proportion they exceed each other, is as yet uncertain. Nor is it probable, that their Numbers are yet known, for they have not been obſerved with due Care, nor their Theories diſcovered, but of late Years. The Ancients were divided in their Opinions concerning them; ſome imagined that they were only a Kind of *Meteors* kindled in our Atmoſphere, and were there again diſſipated; others took them to be ſome ominous Prodigies: But modern Diſcoveries prove, that they are Worlds ſubject to the ſame Laws of Motion as the Planets are; and they muſt be very hard and durable Bodies, elſe they could not bear the vaſt Heat which ſome of them, when they are in their *Perihelia*, receive from the Sun, without being utterly conſumed. The great Comet which appear'd in the Year 1680, was within $\frac{1}{6}$ Part of the Sun's Diameter from his Surface; and therefore its heat muſt be prodigiouſly intenſe beyond Imagination. And when it is at its greateſt Diſtance from the Sun, the Cold muſt be as rigid.

SECT.

SECT. II.

Of the FIXED STARS.

THE fixed Stars are thoſe bright and ſhining Bodies, which in a clear Night appear to us every where diſperſed through the boundleſs Regions of Space. They are term'd fixed, becauſe they are found to keep the ſame immutable Diſtance one from another in all Ages, without having any of the Motions obſerved in the Planets. The fixed Stars are all placed at ſuch immenſe Diſtances from us, that the beſt of Teleſcopes repreſent them no bigger than Points, without having any apparent Diameters.

The fixed Stars are at immenſe Diſtance from us.

It is evident from hence, that all the Stars are luminous Bodies, and ſhine with their own proper and native Light, elſe they could not be ſeen at ſuch a great Diſtance. For the *Satellites* of *Jupiter* and *Saturn*, tho' they appear under conſiderable Angles through good Teleſcopes, yet are altogether inviſible to the naked Eye.

The fixed Stars are luminous Bodies like the Sun.

Although the Diſtance betwixt us and the Sun is vaſtly large, when compared to the Diameter of the Earth, yet it is nothing when compared with the prodigious Diſtance of the fixed Stars; for the whole Diameter of

The Diſtance from us to the Sun is nothing in Compariſon of the vaſt Diſtance of the fixed Stars.

of the Earth's Annual Orbit, appears from the neareſt fixed Star no bigger than a Point, and the fixed Stars are at leaſt 100,000 times farther from us than we are from the Sun; as may be demonſtrated from the Obſervation of thoſe who have endeavoured to find the Parallax of the Earth's Annual Orb, or the Angle under which the Earth's Orbit appears from the fixed Stars.

As to Appearance, the Earth may be conſidered as being the Centre of the Heavens.

Hence it follows, that tho' we approach nearer to ſome fixed Stars at one Time of the Year than we do at the oppoſite, and that by the whole Length of the Diameter of the Earth's Orbit; yet this Diſtance being ſo ſmall in compariſon with the Diſtance of the fixed Stars, their Magnitudes or Poſitions cannot thereby be ſenſibly altered; therefore we may always, without Error, ſuppoſe ourſelves to be in the ſame Center of the Heavens, ſince we always have the ſame viſible Proſpect of the Stars without any Alteration.

The fixed Stars are Suns.

If a Spectator was placed as near to any fixed Star, as we are to the Sun, he would there obſerve a Body as big, and every way like, as the Sun appears to us: and our Sun would appear to him no bigger than a fixed Star: and undoubtedly he would reckon the Sun as one of them in numbering the Stars. Wherefore ſince the Sun differeth nothing from a fixed Star, the fixed Stars may be reckoned ſo many Suns.

It is not reaſonable to ſuppoſe that all the fixed Stars are placed at the ſame Diſtance from us; but it is more probable that they are every where interſperſed thro' the vaſt indefinite Space of the Univerſe; and that there may be as great a Diſtance betwixt any two of them, as there is betwixt our Sun and the neareſt fixed Star. Hence it follows, why they appear to us of different Magnitudes, not becauſe they really are ſo, but becauſe they are at different Diſtances from us; thoſe that are neareſt excelling in Brightneſs and Luſtre thoſe that are moſt remote, who give a fainter Light, and appear ſmaller to the Eye.

The fixed Stars are at vaſt Diſtance from each other.

The Aſtronomers diſtribute the Stars into ſeveral Orders or Claſſes; thoſe that are neareſt to us and appear brighteſt to the Eye, are called Stars of the firſt Magnitude; thoſe that are neareſt to them in Brightneſs and Luſtre, are called Stars of the ſecond Magnitude; thoſe of the third Claſs, are ſtiled Stars of the third Magnitude; and ſo on, until we come to the Stars of the ſixth Magnitude, which are the ſmalleſt that can be diſcerned by the naked Eye. There are infinite Numbers of ſmaller Stars, that can be ſeen through Teleſcopes; but theſe are not reduced to any of the ſix Orders, and are only called *Teleſcopical* Stars. It may be here obſerved, that tho' the Aſtronomers have reduced all the Stars that are viſible to the naked Eye, into ſome one or other of theſe Claſſes, yet we

The Diſtribution of the Stars into 6 Claſſes.

Of *Teleſcopical Stars.*

we are not to conclude from thence that all the Stars anſwer exactly to ſome or other of theſe Orders; but there may be in Reality as many Orders of the Stars as they are in Number, few of them appearing exactly of the ſame Bigneſs and Luſtre.

The Stars digeſted into Conſtellations

The ancient Aſtronomers, that they might diſtinguiſh the Stars, in regard to their Situation and Poſition to each other, divided the whole ſtarry Firmament into ſeveral *Aſteriſms*, or Syſtems of Stars, conſiſting of thoſe that are near to one another. Theſe *Aſteriſms* are called *Conſtellations*, and are digeſted into the Forms of ſome Animals; as Men, Lions, Bears, Serpents, *&c.* or to the Images of ſome known Things; as, of a Crown, a Harp, a Triangle, *&c.*

Zodiac.

The Starry Firmament was divided by the Ancients into 48 Images or Conſtellations; twelve of which they placed in that Part of the Heavens wherein are the Planes of the Planetary Orbits; which Part is called the *Zodiac*, becauſe moſt of the Conſtellations placed therein reſemble ſome living Creature. The two Regions of the Heavens that are on each Side of the *Zodiac*, are called the North and South Parts of the Heavens.

Conſtellations within the Zodiac.

The Conſtellations within the *Zodiac* are, 1. *Aries*, the *Ram*; 2. *Taurus*, the *Bull*; 3. *Gemini*, the *Twins*; 4. *Cancer*, the *Crab*; 5. *Leo*, the *Lion*; 6. *Virgo*, the

Virgin; 7. *Libra*, the *Balance*; 8. *Scorpio*, the *Scorpion*; 9. *Sagittarius*, tha *Archer*; 10. *Capricornus*, the *Goat*; 11. *Aquarius*, the *Water-Bearer*; and, 12. *Piſces*, the *Fiſhes.*

Northern Conſtellations. The Conſtellations on the North Side of the *Zodiac* are Twenty-one, *viz.* the *Little Bear*; the *Great Bear*; the *Dragon*; *Cepheus*, a King of *Ethiopia*; *Bootes*, the Keeper of the *Bear*; the *Northern Crown*; *Hercules* with his Club watching the *Dragon*; the *Harp*; the *Swan*; *Caſſiopeia*; *Perſius*; *Andromeda*; the *Triangle*; *Auriga*; *Pegaſus*, or the *Flying Horſe*; *Equuleus*; the *Dolphin*; the *Arrow*; the *Eagle*; *Serpentarius*; and the *Serpent.*

Southern Conſtellations. The Conſtellations noted by the Ancients on the South Side of the *Zodiac*, were fifteen, *viz.* the *Whale*; the River *Eridanus*; the *Hare*; *Orion*; the *Great Dog*; *Little Dog*; the Ship *Argo*; *Hydra*; the *Centaur*; the *Cup*; the *Crow*; the *Wolf*; the *Altar*; the *Southern Crown*; and the *Southern Fiſh.* To theſe have been lately added the following, *viz.* The *Phænix*; the *Crane*; the *Peacock*; the *Indian*; the *Bird of Paradiſe*; the *Southern Triangle*; the *Fly*; *Cameleon*; the *Flying Fiſh*; *Toucan*, or the *American Gooſe*; the *Water Serpent*, and the *Sword Fiſh.* The Ancients placed thoſe particular Conſtellations or Figures in the

Heavens, either to commemorate the Deeds of ſome great Man, or of ſome notable Exploit or Action; or elſe took them from the Fables of their Religion, *&c.* And the Modern Aſtronomers do ſtill retain them, to avoid the Confuſion that would ariſe by making new ones, when they compare the modern Obſervations with the old ones.

Some of the principal Stars have particular Names given them, as *Syrius*, *Arctu-rus*, *&c.* There are alſo ſeveral Stars that are not reduced into Conſtellations, and theſe are called *Unformed Stars.*

Unformed Stars.

Beſides the Stars viſible to the naked Eye there is a very remarkable Space in the Heavens, called the *Galaxy*, or *Milky Way.* This is a broad Circle of a whitiſh Hue, like Milk, going quite round the whole Heavens, and conſiſting of an infinite Number of ſmall Stars, viſible thro' a Teleſcope, tho' not diſcernible by the naked Eye, by reaſon of their exceeding Faintneſs; yet with their Light they combine to illuſtrate that Part of the Heavens where they are, and to cauſe that ſhining Whiteneſs.

The *Galaxy* or *Milky Way.*

The Places of the fixed Stars, or their relative Situations one from another, have been carefully obſerved by Aſtronomers, and digeſted into Catalogues. The firſt among the *Greeks*, who reduced the Stars into a Catalogue, was *Hypparcus*, who, from his own Obſervations, and of thoſe who lived before him, inſerted 1022 Stars into his Catalogue, about 120 Years before the Chriſtian *Æra:* This Catalogue has been ſince enlarged and improved by ſeveral learned Men, to the Number of 3000, of which there are a great many Teleſcopical, and not to be diſcerned by the naked Eye; and theſe are all ranked in the Catalogue as Stars of the ſeventh Magnitude.

It may ſeem ſtrange to ſome, that there are no more than this Number of Stars viſible to the naked Eye; for ſometimes in a clear Night they ſeem to be innumerable: but this is only a Deception of our Sight, ariſing from their vehement ſparkling, while we look upon them confuſedly, without reducing them into any Order; for there can ſeldom be ſeen above 1000 Stars in the whole Heavens with the naked Eye at the ſame Time; and if we ſhould diſtinctly view them, we ſhall not find many but what are inſerted upon a good *Celeſtial* Globe.

Altho' the Number of Stars that can be diſcerned by the naked Eye are ſo few, yet it is probable there are many more which are beyond the Reach of our Opticks, for thro' Teleſcopes they appear in vaſt Multitudes, every where diſperſed throughout the whole Heavens; and the better our Glaſſes are, the more of them we ſtill diſcover. The ingenious Dr. *Hook* has obſerved 78 Stars in the *Pleiades*, of which the naked Eye is never able to diſcern above 7; and in *Orion*, which has but 80 Stars in the *Britiſh* Catalogue, (and ſome of them Teleſcopical) there has been numbered 2000 Stars.

An Idea of the Univerſe.

Thoſe who think that all theſe glorious Bodies were created for no other Purpoſe, than to give us a little dim Light, muſt entertain a very ſlender Idea of the Divine Wiſdom; for we receive more Light from the *Moon* itſelf, than from all the *Stars* put together. And ſince the *Planets* are ſubject to the ſame Laws of Motion with our *Earth*, and ſome of them not only equal, but vaſtly exceed it in Magnitude, it is not unreaſonable to ſuppoſe, that they are all habitable Worlds. And ſince the *Fixed Stars* are no ways behind our *Sun*, either in Bigneſs or Luſtre, is it not probable, that each of them have a Syſtem of *Planetary Worlds* turning round them, as we do round our Sun? And if we aſcend as far as the ſmalleſt Star we can ſee, ſhall we not then diſcover innumerable more of theſe glorious Bodies, which now are altogether inviſible to us? And ſo *ad infinitum*, thro' the boundleſs Space of the Univerſe. What a magnificent Idea muſt this raiſe in us of the *Divine Being!* Who is every where, and at all TImes preſent, diſplaying his Divine Power, Wiſdom and Goodneſs amongſt all his Creatures!

The

The DESCRIPTION *and* USE *of the* CELESTIAL *and* TERRESTRIAL GLOBES.

Sphere or *Globe.*

A *Globe* or *Sphere* is a round ſolid Body, having every Part of its Surface equally diſtant from a Point within it, called its *Center*; and it may be conceived to be formed by the Revolution of a Semicircle round its Diameter.

Great Circle.

Hemiſpheres.

Any Circle paſſing through the Center of the Sphere, thereby dividing into two equal Parts or Segments, is called a *Great Circle*; and the Segments of the Sphere ſo divided are called *Hemiſpheres.*

Every Great Circle has its Poles and Axis.

Poles.

The *Poles* of a Great Circle are two Points on the Surface of the Sphere diametrically oppoſite to one another, and every where equally diſtant from the ſaid Circle.

Axis.

The *Axis* of a Circle is a right Line paſſing through the Center of the Sphere, and through the Poles of the ſaid Circle, and is therefore perpendicular to the Plane: Therefore

All Circles paſſing through the Poles of any great Circle, interſect it in two Places diametrically oppoſite, and alſo at right Angles; and with reſpect to the ſaid Great Circle, they may be called its *Secundaries*.

Secundaries.

All Circles dividing the Sphere into two unequal Parts, are called *leſſer* or *parallel Circles*, and are uſually denominated by that Great Circle to which they are parallel.

Parallel or leſſer Circles.

The Earth being globular, its outward Parts, as the ſeveral *Countries*, *Seas*, *&c.* are beſt, and moſt naturally repreſented upon the Surfices of a Globe; and when ſuch a Body has the outward Parts of the Earth and Sea delineated upon its Surface, and placed in their natural Order and Situation, it is called a *Terreſtrial Globe*.

Terreſtrial Globe.

The Celeſtial Bodies appear to us as if they were all placed in the ſame Concave Sphere, therefore Aſtronomers place the Stars according to their reſpective Situations and Magnitudes, and alſo the Images of the Conſtellations, upon the external Surface of a Globe; for it anſwers the ſame Purpoſes as if they were placed within a Concave Sphere, if we ſuppoſe the Globe to be tranſparent, and the Eye placed in the Center. A Globe having the Stars placed upon its Surface, as above deſcribed, is called a *Celeſtial Globe*. Theſe Globes are both placed in Frames, with other Appurtenances, as ſhall be deſcribed in a proper Place.

Celeſtial Globe.

The principal Uſes of theſe Globes (beſides their ſerving as *Maps*, to diſtinguiſh the outward Parts of the Earth, and the Situations of the Fixed Stars) is to explain and reſolve the Phænomena ariſing from the diurnal Motion of the Earth round its Axis.

The principal Uſe of the Globes.

It has been ſhewed in the Introduction, that the Diſtance of the Earth from the Sun is no more than a Point, when compared with the immenſe Diſtance of the Fixed Stars; therefore let the Earth be in what Point ſoever of her Orbit, there will be the ſame Proſpect of the Heavens, as a Spectator would obſerve did he reſide in the Sun: And if ſeveral Circles be imagined to paſs thro' the Center of the Earth, and others, parallel to them, be conceived to paſs thro' the Center of the Sun, theſe Circles in the Heavens will ſeem to coincide, and to paſs exactly thro' the ſame Stars. Wherefore as to the Appearances of the Fixed Stars, it is indifferent whether the Earth or the Sun be made the Center of the Univerſe. But becauſe it is from the Earth that we always obſerve the Celeſtial Bodies, and their apparent Motions ſeem to us to be really made in the Heavens, it is more natural in explaining the Phænomena ariſing from theſe Motions, to place the Earth in the Center. And again, becauſe the Semidiameter of the Earth, when compared to her Diſtance from the Sun, is of no ſenſible

There will be the ſame Proſpect of the Fixed Stars, whether the Spectator be placed on the Earth, or in the Sun.

Magnitude, any Point upon the Earth's Surface, let her be in what Part ſoever of the Orbit, may be conſidered as being the Center of the Univerſe. Upon theſe Principles, the different Phænomena ariſing from the diurnal Motion of the Earth, and the different Situation of a Spectator upon its Surface, are very naturally illuſtrated and explained by the Globes.

As to the Alterations of Seaſons, *&c.* ariſing from the annual Motion of the Earth round the Sun, it is indifferent which we ſuppoſe to move, the Earth, or the Sun; for in both Caſes the Effect will be the ſame: Wherefore becauſe it is the Sun that appears to us to move, we ſay the Sun is in ſuch a Part of the Ecliptic, without attributing any Motion to the Earth, any more than if ſhe had actually been at Reſt. For the ſame Reaſon we ſay the Sun riſes, or the Sun ſets; by which we mean, that he begins to appear or diſappear, without conſidering in the leaſt how theſe Effects are produced. Theſe Things are here mentioned, to obviate the Objections that might be made by Beginners, after they had been told that the Sun ſtands ſtill.

SECT. I.

An Explanation of the Circles of the Sphere, and of ſome Aſtronomical Terms ariſing therefrom.

IN Order to determine the relative Situations of Places upon the Earth, as well as the Poſitions of the fixed Stars, and other Celeſtial Phænomena, the Globe of the Earth is ſuppoſed to be inviron'd by ſeveral imaginary Circles, and theſe are called the *Circles of the Sphere.* Theſe imaginary Circles are either fixed, and always obtain the ſame Poſition in the Heavens, or moveable, according to the Poſition of the Obſerver.

The *Circles of the Sphere.*

Thoſe Circles that are fixed, owe their Origin to the two-fold Motion of the Earth, and are the *Equator*, the *Ecliptic*, with their *Secundaries* and *Parallels.* Theſe fixed Circles are uſually delineated upon the Surface of the Globes.

The moveable Circles are only the *Horizon*, its *Secundaries* and *Parallels:* Theſe are repreſented by the Wooden Frame, and the Braſs Ring, wherein the Globe is hung, and a thin Plate of Braſs to be ſcrewed in a proper Place upon the ſaid Ring, as Occaſion requires.

I. *Of the Equinoctial.*

The *Equator* or *Equinoctial.*

I. The *Equator* or the *Equinoctial*, is that Great Circle in the Heavens, in whoſe Plane the Earth performs her diurnal Motion round her Axis; or it is that Great Circle, parallel to which the whole Heavens ſeem to turn round the Earth from Eaſt to Weſt in 24 Hours.

Note, The Equator and the Equinoctial are generally ſynonymous Terms; but ſometimes the Equator particularly ſignifies that Great Circle upon the Surface of the Earth, which coincides with the Equinoctial in the Heavens. This Circle is alſo by Mariners commonly called the *Line*.

Northern and *Southern Hemiſpheres.*

The *Axis of the World.*

Poles of the World, or *of the Equator.*

The Equinoctial divides the Globe of the Earth, and alſo the whole Heavens into two equal Parts, North and South, which are called the *Northern* and *Southern Hemiſpheres*. The Axis of this Circle is called the *Axis of the World*, or the *Earth's Axis*, becauſe the Earth revolves about it (from Weſt to Eaſt) in 24 Hours. The Extremes of this Axis are called the *Poles of the World*, whereof that which lies in the Northern Hemiſphere, is called the *North Pole*, and the other is called the *South Pole*.

The Equinoctial Circle is always delineated upon the Surface of each Globe, with its Name at length expreſſed; the Axis of this Circle or the Earth's Axis, is only an imaginary Line in the Heavens, but on the Globes it is expreſſed by the Wires about which they really turn. The Poles of the World are the two Points upon the Surface of the Globe through which theſe Wires paſs; the North Pole is that which hath the little Braſs Circle, with a moveable Index placed around it; and the other oppoſite to it is the South Pole. The Northern Hemiſphere is that wherein the North Pole is placed, and the oppoſite one is the Southern Hemiſphere.

The Aſtronomers divide all Circles into 360 equal Parts, called *Degrees*, each Degree into 60 equal Parts, called *Minutes*, each Minute into 60 *Seconds*, &c. But beſides this Diviſion into Degrees, the Equinoctial is alſo divided into 24 equal Parts or *Hours*, each Hour into 60 *Minutes*, each Minute into 60 *Seconds*, &c. ſo that one Hour is equal to 15 Degrees, each Minute of Time is equal to 15 Minutes of a Degree, *&c.*

2. All Circles conceived to paſs through the Poles of the World, interſecting the Equinoctial at right Angles, are with reſpect to any Point in the Heavens called *Hour Circles*; and alſo *Circles of Aſcenſion*, be-

Hour Circles, or *Circles of Aſcenſion*, alſo called *Meridians*.

becauſe the Aſcenſion of the heavenly Bodies, from a certain Point, are by them determined.

Theſe Circles are alſo, with regard to Places upon Earth, call'd *Meridians.*

The *Meridians* are commonly drawn upon the Terreſtrial Globe thro' every 15 Degrees of the Equinoctial, thereby making an Hour difference betwixt the Places through which they paſs. On the Celeſtial Globe there are commonly drawn but two of theſe *Meridians*, croſſing the Equinoctial in four Points equidiſtant from one another, thereby dividing it into four Quadrants; but the intermediate ones are here ſupplied, and alſo upon the Terreſtrial Globe, by the Braſs Circle on which they are hung, which is therefore called the *Braſs Meridian*, and ſometimes only the *Meridian*, it ſerving for this Purpoſe to all the Points upon either Globe.

The *Braſs Meridian.*

There is alſo a little Braſs Circle fixed upon this Meridian, divided into 24 Hours, having an Index moveable round the Axis of the Globe to be turned to any particular Hour. The Uſe of this Circle is to ſhew the Difference of Time betwixt any two Meridians, and is therefore called the *Hour-Circle.*

The *Hour Circle.*

3. All Circles parallel to the Equinoctial are with reſpect to any Point in the Heavens, called *Parallels of Declination.* So that,

Parallels of Declination.

4. The *Declination of any Point* in the Heavens (as of the *Sun*, a *fixed Star*, or the like) is an Arch of the Meridian paſſing through that Point, and intercepted betwixt it and the Equator; and if the ſaid Point be to the $\left\{\begin{array}{l}\text{Northward}\\\text{Southward}\end{array}\right\}$ of the Equator, it is called $\left\{\begin{array}{l}\textit{North}\\\textit{South}\end{array}\right\}$ *Declination.*

Declination North or *South.*

Of the Parallels of Declination, four are eminently diſtinguiſhed by particular Names, *viz.* The two *Tropics*, and the two *Polar Circles.*

Tropics and *Polar Circles.*

The Tropics are on different Sides of the Equator, each 23 Degrees and 29 Minutes diſtant from it, that which lies in the Northern Hemiſphere, it called the *Tropic of Cancer*; and the Southern one, the *Tropic of Capricorn.*

Tropic of Cancer; of Capricorn.

Theſe Circles are the Limits of the Sun's greateſt Declination, and are called Tropics, becauſe whenever the Sun arrives to them, he ſeems to return back again towards the Equator.

6. The *Polar Circles* are each of them at the ſame Diſtance from the Poles of the World, that the Tropics are from the Equator, *viz.* 23° 29′. That which lies near the North Pole, is called the *Arctic Circle*, from *Arctos*, a Conſtellation ſituated in the Heavens near that Place; whence alſo this Pole is ſometimes called the *Arctic Pole.*

Arctic Circle.

Arctic Pole.

The other Polar Circle, which is ſituated near the South Pole, is called the *Antarctic Circle*, becauſe its Poſition is contrary to the other; and the South Pole is ſometimes called the *Antarctic Pole*.

Antarctic Circle.

Antarctic Pole.

The Tropics and the Polar Circles have each their Names expreſſed upon the Globes.

II. *Of the Ecliptic.*

Ecliptic.

7. The *Ecliptic* is that great Circle in whoſe Plane the Earth performs its annual Motion round the Sun; or, in which the Sun ſeems to move round the Earth once in a Year. This Circle makes an Angle with the Equinoctial of 23 Degrees, 29 Minutes, and interſects it in two oppoſite Points, which are called the *Equinoctial Points*; and the two Points in the Ecliptic that are at the greateſt Diſtance from the Equinoctial Points, are called the *Solſtitial Points*. The two Meridians paſſing through thoſe Points are, by Way of Eminence, called *Colures*; whereof that which paſſeth thro' the Equinoctial Points is called the *Equinoctial Colure*; and that whieh is at Right Angles to it, paſſing through the Solſtitial Points, is called the *Solſtitial Colure*.

Equinoctial Points.

Solſtitial Points.

Colures.

Equinoctial Colure

Solſtitial Colure.

The Ecliptic divided into Signs.

The Ecliptic is divided into 12 equal Parts, called *Signs*, each Sign being 30 Degrees, beginning from one of the Equinoctial Points, and numbered from Weſt to Eaſt;

the Names and Characters of the 12 Signs are as follows: *viz.*

Aries,	*Taurus,*	*Gemini,*	*Cancer,*	*Leo,*	*Virgo.*
1. ♈	2. ♉	3. ♊	4. ♋	5. ♌	6. ♍
Libra,	*Scorpio,*	*Sagittarius,*	*Capricornus,*	*Aquarius,*	*Piſces,*
7. ♎	8. ♏	9. ♐	10. ♑	11. ♒	12. ♓

Northern Signs.

The firſt ſix of theſe are called the *Northern Signs,* and poſſeſs that half of the Ecliptic which is to the Northward of the Equator; beginning with the firſt Point of ♈, and ending with the laſt Point of ♍.

Southern Signs.

The latter ſix are call'd the *Southern Signs,* becauſe they poſſeſs the Southern Half of the Ecliptic, beginning at the firſt Point of ♎, and ending with the laſt Point of ♓.

The Diviſion of the Ecliptic into Signs, and the Names of the Colours, are particucularly expreſſed upon the Globes.

The Signs of the Ecliptic took their Names from 12 Conſtellations mentioned in the Introduction to be ſituated in the Heavens near thoſe Places. It is to be obſerved, that the Signs are not to be confounded with the Conſtellations of the ſame Name: For the *Sign of Aries* is not the ſame with the *Conſtellation* Aries; the latter is a Syſtem of Stars digeſted into the Figure of a *Ram*; but the Sign of *Aries* is only 30 Degrees of the Ecliptic counted from the Equinoctial Point ♈, (which is reckon'd the firſt Point in the Ecliptic) to the Beginning of *Taurus:* Or, it is ſometimes taken for all that Space upon the Celeſtial Globe contained between the two Circles paſſing through the firſt Points of ♈ and ♉. What has been here ſaid of *Aries*, is to be noted of all the reſt of the Signs.

The Conſtellations above-mentioned were formerly ſituated within the Signs which now bear their Names; but by a ſlow Motion of the Equinoctial Points, being one Degree in 72 Years, the Conſtellation *Aries* has now got into the Sign ♉, and ſo of the reſt. So that *Piſces* is now got into the Sign of ♈; this ſlow Motion in the Heavens is called the *Proceſſion of the Equinoxes.*

By this Motion we ſhall have the Seaſons of the Year fall at quite oppoſite Times, *viz.* the Summer Solſtice in *December*, and the Winter in *June.*

Poles of the Ecliptic.

The *Poles of the Ecliptic* are both ſituated in the Solſtitial Colure, at 23 Degrees, 29 Minutes Diſtance from the Pole of the World; and they take their Denomination from the Hemiſphere wherein they are plac'd, *viz.* that which lies in the $\left\{\begin{matrix}\text{Northern}\\ \text{Southern}\end{matrix}\right\}$ Hemiſphere, is called the $\left\{\begin{matrix}\text{North}\\ \text{South}\end{matrix}\right\}$ Pole of the Ecliptic. The Arctic and Antarctic Circles are deſcribed by the Poles of the Ecliptic in the Diurnal Motion of the Earth round its Axis, whence it ſeems theſe two Circles are called *Polar.*

8. All great Circles paſſing through the Poles of the Ecliptic, and conſequently in-

interſecting it at right Angles, are called *Circles of Longitude*: So that,

Circles of Longitude.

9. The *Longitude* of any *Point* in the Heavens, (as a *Star* or *Planet*, &c.) is an Arch of the Ecliptic contained between the Circle of Longitude paſſing thro' that Point, and the Equinoctial Point ♈. And that Degree of any Sign which lies under the Circle of Longitude, paſſing thro' any Star or Planet, is called the *Place* of that Star or Planet.

Longitude of any Point in the Heavens.

Place of a Star.

Note, The *Sun* never goes out of the Ecliptic, and it is not uſual to ſay the Sun's Longitude, but we commonly expreſs it the *Sun's Place*, which is that Sign, Degree, Minute, &c. of the Ecliptic, which he at any Time paſſes.

10. All Circles conceived to be drawn parallel to the Ecliptic, are called *Parallels of Latitude*: So that,

11. The *Latitude* of any Point in the Heavens, (as a Fixed Star, &c. is an Arch of the Circle of Longitude, in paſſing thro' that Point, and intercepted betwixt it and the Ecliptic; or, the Latitude is the Diſtance from the Ecliptic; and if the ſaid Point be to the Northward of the Ecliptic, it is called North Latitude; but if it be to the Southward, it is called South Latitude.

Latitude of a Star, &c.

Upon the *Terreſtrial Globe* none of the Circles of Longitude are deſcribed; and upon the *Celeſtial*, they are commonly drawn thro' the Beginning of every *Sign*; but they are all ſupplied upon both Globes, by faſtening a thin Plate of Braſs over one of the Poles of the Ecliptic, and ſo as to be moved to any Degree thereof at Pleaſure. The Parallels of Latitude are alſo ſupplied by the Graduations upon the ſaid Plate, as ſhall be ſhewn in a proper Place.

We have now done with all thoſe Circles that are fixed, and ſuch as are drawn upon the Globes themſelves; we next proceed to the moveable Circles.

III. *Of the Horizon.*

Horizon.

12. The *Horizon* is that great Circle which divides the upper or viſible Hemiſphere of the World, from the lower or inviſible: This Circle is diſtinguiſhed into two Sorts, the *Senſible*, and the *Rational.*

Senſible Horizon.

The *Senſible*, or *Apparent Horizon*, is that Circle which limits or determinates our Proſpect, whether we are at Land or Sea, reaching as far as we can ſee; or it is that Circle where the Sky and the Earth, or Water ſeem to meet. When we are on *Terra Firma*, this Circle commonly ſeems rugged and irregular, occaſioned by the Unevenneſs of the Ground terminating our Proſpect; but at Sea there are no ſuch Irregularities; the Semidiameter of this Circle varieth according to the Height of the Eye of the Obſerver; if a Man of ſix Feet high ſtood upon a large Plain, or the ſurface of the Sea, he could not ſee above three Miles round.

This Circle determines the Riſing and Setting of the Heavenly Bodies, and diſtinguiſhes Day and Night.

Rational Horizon.

The *Rational* or true *Horizon* is a great Circle paſſing thro' the Center of the Earth parallel to the ſenſible Horizon, being diſtant from it by the Earth's Semidiameter, which is about 3980 Miles: This Diſtance is nothing in Compariſon of the immenſe Diſtance of the Sun and the fixed Stars, therefore Aſtronomers make no Diſtinction between theſe two Circles, but conſider the apparent Horizon, or that wherein the Sun appears to riſe and ſet, as paſſing thro' the Center of the Earth.

Cardinal Points of the Horizon.

This Circle is divided by Aſtronomers into four Quadrants, and each of the Quadrants into 90 Degrees, *&c.* The four Points quartering this Circle are called the *Cardinal Points*, and are termed the *Eaſt*, *Weſt*, *North* and *South*. The *Eaſt* is that Point of the Horizon where the Sun riſes when he is in the Equinoctial, or on that Day when he aſcends above the Horizon exactly at ſix o'Clock; and the *Weſt* is that Point of the Horizon which is directly oppoſite to the Eaſt, or where the Sun ſets when he is in the Equinoctial. The *South* is 90 Degrees diſtant from the Eaſt and Weſt, and is towards that Part of the Heavens wherein the Sun always appears to us in *Great Britain* at Noon; and the *North* is that Part of the Heavens which is directly oppoſite to the South: Or the North and South Points of the Heavens may be found by turning yourſelf either directly towards the Eaſt or the Weſt: If you look towards the $\left\{\begin{matrix}\text{Eaſt}\\ \text{Weſt}\end{matrix}\right\}$ the $\left\{\begin{matrix}\text{South}\\ \text{North}\end{matrix}\right\}$ will be to the Right Hand, and the $\left\{\begin{matrix}\text{North}\\ \text{South}\end{matrix}\right\}$ to the Left.

Points of the Compaſs. Beſides the aforementioned Diviſion of the Horizon into Degrees, *Mariners* divide it into 32 equal Parts, which they call the *Points of the Compaſs*; to each of which Points they gave a particular Name, compounded of the four Cardinals, according to what Quarter of the Compaſs is intended.

The Center of the Horizon is the Place of Obſervation, and the Poles of it are, one *Zenith.* exactly over our Heads, called the *Zenith*; and the other exactly under our Feet, called *Nadir.* the *Nadir*.

13. All Circles conceived to paſs thro' *Vertical Circles.* the Zenith and Nadir, are called *Vertical Circles*, or *Azimuths*. Of theſe Circles, that which paſſes thro' the North and South *Meridian.* Points of the Horizon, is called the *Meridian*; ſo that when any Object is upon the Meridian, it then bears either due South *Azimuth.* or due North from us; and the *Azimuth* of

any Object is an Arch of the Horizon intercepted between the Vertical Circle paſſing through it, and either the North or South Part of the Meridian; which Part is commonly ſpecified.

The Meridian paſſes thro' the Poles of the World, as well as through the Zenith and Nadir, and therefore is a Secundary both of the Equinoctial and the Horizon: This Circle divides the Globe into the *Eaſtern* and *Weſtern Hemiſpheres*, and the Poles of it are the *Eaſt* and *Weſt* Points of the *Horizon*. All the heavenly Objects are, during one Half of their Continuance above the Horizon, in the Eaſtern Hemiſphere, and for the other Half in the Weſtern; ſo that whenever the Sun arrives upon the upper Part of the Meridian, it is then *Noon* or *Mid-day*, which is the Reaſon why this Circle is called the Meridian; and when he comes to the lower Part, it is then *Midnight*.

Prime Vertical.

The Vertical Circle paſſing thro' the Eaſt and Weſt Points of the Horizon, is called the *Prime Vertical*, or *Circle* of *Eaſt* and *Weſt*; ſo that when any Object is upon this Circle in the Eaſtern Hemiſphere, it appears due Eaſt; and if it be in the Weſtern Hemiſphere, it appears due Weſt.

Amplitude

That Degree in the Horizon wherein any Object riſes or ſets from the Eaſt or Weſt Points, is called the *Amplitude*; which for Riſing is called *Amplitude Ortive*, and Oc-

Occaſive for ſetting; which muſt be alſo denominated whether it be Northerly or Southerly.

It may be obſerv'd, that the *Amplitude* and *Azimuth* are much the ſame; the Amplitude ſhewing the Bearing of any Object when he riſes or ſets, from the Eaſt or Weſt Points of the Horizon; and the Azimuth the Bearing of any Object when it is above the Horizon, either from the North or South Points thereof. As for Example, if an Object riſes or ſets within 10 Degrees of the Eaſt or Weſt, ſuppoſe towards the South, we accordingly ſay, its *Amplitude* is 10 Degrees Southerly; but if an Object, that is of any Height above the Horizon, ſhould be in the Vertical Circle, paſſing thro' the before-mentioned Point, we then ſay, its *Azimuth* is 80 Degrees from the South, or 100 Degrees from the North, both which Expreſſions ſignify the ſame.

14. All Circles drawn parallel to the Horizon, in the upper Hemiſphere, are called *Almacanthers*, or *Parallels of Altitude*: So that the *Altitude* of any Point in the Heavens is an Arch of the Vertical Circle paſſing thro' that Point, and intercepted betwixt it and the Horizon; and if the Object be upon the Meridian, it is commonly called the *Meridian Altitude*. The Complement of the Altitude, or what it wants of 90 Degrees, is called the *Zenith Diſtance*.

Almacanthers. *Altitudes.*

Meridian Altitude.

Zenith Diſtance.

The Horizon (by which we mean the Rational) is repreſented by the upper Surface of the Wooden Frame, wherein the Globes are placed; upon this Horizon are deſcribed ſeveral Concentrick Circles, the Innermoſt of which is divided into Degrees, which ought to be numbered both Ways from the Eaſt and the Weſt, until they end at 90 Degrees in the North and South Points. The Uſe of theſe Diviſions is to ſhew the Amplitudes of the Sun and Stars, at their Riſing and Setting: Alſo in ſome convenient Place upon this Horizon, there is commonly noted the Points of the Compaſs. Without the before-mentioned Circle there is drawn the Ecliptic, with its Diviſions, into Signs and Degrees, and a Circle of Months and Days: The Uſe of theſe two Circles is to ſerve as a Kalendar to ſhew the Sun's Place at any Time of the Year, and by that Means to find his Place in the *Ecliptic* drawn upon the Globe itſelf.

The *Vertical Circles*, and the *Parallels of Altitude*, are ſupplied by a thin Plate of Braſs, having a Nut and Screw at one End to faſten it to the Braſs Meridian in the Zenith Point; which being done, the lower End of it may be put between the Globe itſelf and the inner Edge of the Horizon, and ſo turned round about to any Point required. The fiducial

Edge thereof repreſenting the *Vertical Circles*, and the *Degrees* upon it, deſcribing the Parallels of Altitude. This thin Plate is called the *Quadrant of Altitude*.

Quadrant of Altitude.

The Center of the Horizon being the Place of Obſervation, it is evident that this Circle, and all the others belonging to it, are continually changed, which Way ſoever we move; wherefore we may ſuppoſe the Horizon, with its Secundaries and Parallels, to inveſt the Globe like a *Rete* or Net; and to be moveable every Way round it. This is very naturally illuſtrated by the Globes; if we move directly North or directly South, the Change made in the Horizon is repreſented by moving the Braſs Meridian (keeping the Globe from turning about its Axis) in the Notches made in the Wooden Horizon, juſt ſo much as we travelled. If our Courſe ſhould be due Eaſt or due Weſt, the Alterations made thereby are repreſented by turning the Globe accordingly about its Axis, the Braſs Meridian being kept fixed; and if we ſteer betwixt the Meridian and the Eaſt or Weſt Points, then we are to turn the Braſs Meridian, and alſo the Globe, about its Axis accordingly; the Sum of which is, let the Spectator be in what Point ſoever of the Earth's Surface, he'll there gravitate or tend exactly towards its Center, and imagine himſelf to be on the higheſt Part thereof, (the Unevenneſs of the Ground not being here conſidered; wherefore if we turn the Globe in ſuch a Manner as to bring the ſeveral progreſſive Steps of a Traveller ſucceſſively to the Zenith, we ſhall then have the ſucceſſive Alterations made in the Horizon, in every Part of his Journey. This Explication being well conſidered, will be of Help to Beginners, to conceive how the Earth is every where habitable, and how Paſſengers can travel quite round it; for ſince every Thing tends towards the Center of the Earth, we are to conceive that Point as being the loweſt, and not to carry our Idea of downwards any farther: Thoſe that are diametrically oppoſite to us being as much upon the upper Part of the Earth as we are, there being no ſuch Thing in Nature as one Place being higher than another, but as it is at a greater Diſtance from the Center of the Earth, let it be in what Country ſoever.

We have now done with all the Circles of the Sphere, and it may be obſerved, that the *Equinoctial*, the *Ecliptic*, and the *Horizon*, with their Secundaries and Parallels, are all alike; and altering their Poſition, may be made to ſerve for one another. Thus, if the *Poles of the World* be brought into the *Zenith* and *Nadir*, the *Equinoctial* will coincide with the *Horizon*, the *Meridians* will be the ſame with the *Vertical Circles*, and the Parallels of *Declination* will be the Parallels of *Altitude*. After the ſame Manner, if ſhifting the Poſition we bring the *Ecliptic* to coincide with the *Horizon*, the Circles of *Longitude* will be the *Vertical Circles*, and the Parallels of *Latitude* and *Altitude* will coincide.

The Horizon and the Equator may be either parallel, perpendicular, or oblique to each other.

Parallel Sphere. 15. A *Parallel Sphere* is that Poſition where the Equator coincides with the Horizon, and conſequently the Poles of the World are in the Zenith and Nadir: The Inhabitants of this Sphere (if there be any) are thoſe who live under the Poles of the World.

Right Sphere. 16. A *Right* or *Direct Sphere* is that Poſition where the Equator is perpendicular to the Horizon, the Inhabitants whereof are thoſe who live under the Equinoctial.

Oblique Sphere. 17. An *Oblique Sphere* is when the Equinoctial and the Horizon make oblique Angles with each other, which every where happens but under the Equator and the Poles.

Diurnal and Nocturnal Arch, The Arch of any Parallel or Declination, which ſtands above the Horizon, is called the *Diurnal Arch*; and the remaining Part of it, which is below the Horizon, is called the *Nocturnal Arch*.

That Point of the Equinoctial which comes to the $\left\{\begin{array}{l}\text{Eaſtern}\\ \text{Weſtern}\end{array}\right\}$ Part of the Hozon, with any Point of the Heavens, is called the $\left\{\begin{array}{l}\text{Aſcenſion}\\ \text{Deſcenſion}\end{array}\right\}$ of that Point, counted from the Beginning of ♈; and if it be in a right Sphere, the Aſcenſion or Deſcenſion is called Right; but if it be in an oblique Sphere, it is called an oblique Aſcenſion or Deſcenſion. So that,

Right Aſcenſion.

18. The *Right Aſcenſion* of the *Sun*, *Moon*, or any *Star*, &c. is an Arch of the Equator contained betwixt the Beginning of ♈, and that Point of the Equinoctial which riſes with them in a *Right Sphere*, or which comes to the Meridian with them is an oblique Sphere.

Oblique Aſcenſion.

19. *Oblique Aſcenſion*, or *Deſcenſion*, is an Arch of the Equinoctial intercepted between the Beginning of ♈, and that *Point* of the *Equator* which riſes or ſets with any Point in the Heavens in an oblique Sphere.

Aſcenſional Difference.

20. *Aſcenſional Difference*, is the Difference betwixt the right and oblique Aſcenſion or Deſcenſion, and ſhews how long the Sun riſes or ſets before or after the Hour of Six.

IV. *Of the Diviſion of Time.*

The Parts that Time is diſtinguiſhed into are *Days*, *Hours*, *Weeks*, *Months*, and *Years*.

A Day is either Natural or Artificial.

Natural and *Artificial Day:*

A *Natural Day* is the Space of Time elapſed while the Sun goes from any Meridian or Horary Circle, till he arrives to the ſame again; or, it is the Time contain'd from Noon, or any particular Hour, to the next Noon, or the ſame Hour again: An *Artificial Day* is the Time betwixt the Sun's Riſing and Setting; to which is oppoſed the *Night*, that is, the Time the Sun is hid under the Horizon.

Hours, &c.

The *Natural Day* is divided into 24 *Hours*, each Hour into 60 *Minutes*, each Minute into 60 *Seconds*, &c. The *Artificial Days* are always unequal to all the Inhabitants that are not under the Equator, except when the Sun is in the Equinoctial Points ♈ and ♎, which happens (according to our Way of reckoning) about the 21ſt of *March* and 23d of *September*; at thoſe Times the Sun riſes at ſix and ſets at ſix, to all the Inhabitants of the Earth. Theſe Days are called the *Equinoxes*, or *Equinoctial Days*; the firſt of which, or when the Sun is in the firſt Point of *Aries*, is called the *Vernal Equinox*, and the latter is called the *Autumnal Equinox*. In all Places where the Sun deſcends below the Horizon, excepting under the Equator, the Days continually lengthen or ſhorten, and that faſter or ſlower, according as the Sun is nearer to or further from the Equinoctial, until he arrives to either of the *Solſtitial Points* ♋ or ♑. At thoſe Times the Sun ſeems to ſtand ſtill for a few Days, and then

Equinoxes.

Vernal and *Autumnal Equinox.*

then he begins to return with a ſlow Motion towards the Equinoctial, ſtill haſtening his Pace as he comes nearer to it: The Sun enters the Tropicks of ♋ and ♑, about the 21ſt of *June*, and the 22d of *December*, which Days are ſometimes called the *Solſtices*; the firſt of which we call the *Summer Solſtice*, and the latter the *Winter Solſtice*.

Solſtices. *Summer* and *Winter Solſtice.*

All Nations do not begin their Day, and reckon their Hours alike. In *Great-Britain*, *France* and *Spain*, and in moſt Places in *Europe*, the Day is reckoned to begin at Midnight, from whence is counted 12 Hours till Noon, then twelve Hours more till next Midnight, which makes a compleat Day; yet the *Aſtronomers* (in theſe Countries) commonly begin their Day at Noon, and ſo reckon 24 Hours till next Noon, and not twice twelve, according to the vulgar Computation,

The Different Beginning of the Day.

The *Babylonians* began their Day at Sun-riſing, and reckoned 24 Hours till he roſe again! This Way of Computation we call the *Babyloniſh Hours*. In ſeveral Parts of *Germany* they count their Hours from Sun-ſetting, calling the firſt Hour after the Sun has ſet, the firſt Hour, *&c.* till he ſets the next Day, which they call the 24th Hour: Theſe are commonly called the *Italian Hours*. According to both theſe Ways of Computation, their Hours are commonly either a little greater or leſs than the $\frac{1}{24}$ Part of a natural Day, in Proportion as the Sun riſes or ſets

Babyloniſh Hours.

Italian Hours.

ſets ſooner or later in the ſucceeding Days. They have alſo this Inconvenience, that their Mid-day and Midnight happen on different Hours, according to the Seaſons of the Year.

Jewiſh Hours. The *Jews* and the *Romans* formerly divided the artificial Days and Nights each into 12 equal Parts; theſe are termed the *Jewiſh Hours*, and are of different Lengths according to the Seaſons of the Year; a *Jewiſh Hour* in Summer being longer than one in Winter, and a Night-Hour ſhorter. This Method of Computation is now in Uſe among the *Turks*, and the Hours are ſtiled the *firſt Hour*, *ſecond Hour*, &c. of the Day or Night; ſo that *Mid-day* always falls upon the ſixth Hour of the Day. *Planetary Hours.* Theſe Hours are alſo called *Planetary Hours*, becauſe in every Hour one of the ſeven Planets were ſuppoſed to preſide over the World, and ſo take it by Turns. The firſt Hour after Sun-riſing on *Sunday* was allotted to the *Sun*; the next to *Venus*; the third to *Mercury*; and the reſt in Order to the *Moon*, *Saturn*, *Jupiter*, and *Mars*. By this Means on the firſt Hour of the next Day the Moon preſided, and ſo gave the Name to that Day; and ſo ſeven Days by this Method had Names given them from the Planets that were ſuppoſed to govern on the firſt Hour.

A Week. A *Week* is a Syſtem of ſeven Days, in which each Day is diſtinguiſhed by a different Name. In moſt Countries theſe Days are called after the Names of the ſeven Planets, as above noted. All Nations that have any Notion of Religion, lay apart one Day in ſeven for public Worſhip; the Day ſolemniz'd by *Chriſtians* is *Sunday*, or the firſt Day of the Week, being that on which our Saviour roſe from the Grave, on which the Apoſtles afterwards uſed more particularly to aſſemble together to perform Divine Worſhip. The *Jews* obſerved *Saturday*, or the ſeventh Day of the Week, for their Sabbath, or Day of Reſt, being that appointed in the fourth Commandment under the Law. The *Turks* perform their Religious Ceremonies on *Friday*.

A *Month.*

A *Month* is properly a certain Space of Time meaſured by the Moon in its Courſe round the Earth. A *Lunar Month* is either *Periodical* or *Synodical.* A *Periodical Month* is that Space of Time the Moon takes to perform her Courſe from one Point of the Ecliptic till ſhe arrives to the ſame again, which is 27 Days and ſome odd Hours; and a *Synodical Month* is the Time betwixt one New Moon, and the next New Moon, which is commonly about 29½ Days. But a *Civil Month* is different from theſe, and conſiſts of a certain Number of Days, fewer or more, according to the Laws and Cuſtoms of the Country wherein they are obſerved.

Periodical and *Synodical Months.*

The compleateſt Period of Time is a *Year*, in which all the Variety of Seaſons return, and afterwards begin a-new. A *Year* is either *Aſtronomical* or *Civil*. An *Aſtronomical Year* is either a *Sydereal*, wherein the Sun departing from a fixed Star, returns to it again; or *Tropical*, which is the Space of Time the Sun takes to perform his Courſe from any Point of the Ecliptic till he returns to it again.

A *Year Sydereal* and *Tropical*.

A *Tropical Year* conſiſts of 365 Days, 5 Hours and 49 Minutes; this is the Time in which all the Seaſons compleatly return, which is a ſmall Matter leſs than a Sydereal Year.

The *Civil Year* is the ſame with the *Political* eſtabliſhed by the Laws of a Country, and is either moveable or immoveable. The moveable Year conſiſts of 365 Days, being leſs than the Tropical Year by almoſt ſix Hours, and is called the *Egyptian Year*, becauſe obſerved in that Country.

Egyptian Year.

The *Romans* divided the Year into 12 Kalendar Months, to which they gave particular Names, and are ſtill retain'd by moſt of the *European* Nations, *viz.* *January*, *February*, *March*, *April*, *May*, *June*, *July*, *Auguſt*, *September*, *October*, *November*, and *December*. The Number of Days in each Month may be known by the following Verſes:

Thirty Days hath September,
April, June, *and* November;
February *hath Twenty-eight alone,*
And all the reſt have Thirty-one.

The Year is alſo divided into four Quarters or Seaſons, *viz.* the *Spring*, *Summer*, *Autumn*, and *Winter*. Theſe Quarters are properly made when the Sun enters into the Equinoctial and Solſtitial Points of the Ecliptic; but in Civil Uſes they are differently reckon'd according to the Cuſtoms of ſeveral Countries. In *England* we commonly reckon the firſt Day of *January* to be the firſt in the Year, which is therefore vulgarly called *New-Year's-Day*; but in Political and Eccleſiaſtical Affairs, the Year is reckon'd to commence on *Lady-Day*, which is the 25th of *March*; and from thence to *Midſummer-Day*, which is the 24th of *June*, is reckon'd the firſt Quarter; from *Midſummer-Day* to *Michaelmas-Day*, which is the 29th of *September*, is the ſecond Quarter; the third Quarter is reckon'd from *Michaelmas-Day* to *Chriſtmas-Day*, which is the 25th of *December*; and from *Chriſtmas-Day* to *Lady-Day*, is reckon'd the laſt Quarter in the Year. In common Affairs, a Quarter is reckon'd from a certain Day to the ſame in the fourth Month following. Sometimes a Month is reckon'd four

Weeks, or 28 Days, and ſo a Quarter 12 Weeks. To all the Inhabitants in the $\left\{\begin{matrix}\text{Northern}\\ \text{Southern}\end{matrix}\right\}$ Hemiſphere, their *Midſummer* is properly when the Sun is in the Tropic of $\left\{\begin{matrix}\textit{Cancer,}\\ \textit{Capricorn,}\end{matrix}\right\}$ and their *Midwinter* at the oppoſite Time of the Year; but thoſe who live under the Equinoctial have two Winters, *&c.* when the Sun is in either Tropic; tho' indeed properly, there is no Seaſon that may be called Winter in thoſe Parts of the World.

The *Egyptian* Year of 365 Days being leſs than the true Solar Year by almoſt ſix Hours, it follows, that four ſuch Years are leſs than four Solar Years by a whole Day; and therefore in 365 Times four Years, that is, in 1460 Years, the Beginning of the Years move through all the Seaſons. To remedy this Inconveniency, *Julius Cæſar* (conſidering that the ſix Hours, which remain at the End of every Year, will in 4 Years make a Natural Day) ordered that every fourth Year ſhould have an intercalary Day, which therefore conſiſts of 366 Days; the Day added was put in the Month of *February*, by poſtponing St. *Matthias*'s Day, which in common Years falls on the 24th, to the 25th of the ſaid Month, all the fixed Feaſts in the Year from thenceforwards falling a Week-day later than otherwiſe they would.

Biſſextile, or *Leap Year.*

According to the *Roman* Way of reckoning, the 24th of *February* was the ſixth of the Kalends of *March*, and it was ordered that for this Year there ſhould be two ſixths, or that the ſixth of the Kalends of *March* ſhould be twice repeated; upon which Account the Year was called *Biſſextile*, which we now call the *Leap-Year*.

To find whether the Year of our Lord be Leap-Year, or the firſt, ſecond, or third after; divide it by four, and the Remainder, if there be any, ſhews how many Years it is after Leap-Year; but if there be no Remainder, then that Year is Leap-Year: Or, you may omit the Hundreds and Scores, and divide the Reſidue by 4, *Examp.* 1757, omiting the Hundreds and the Twentys, I divide the Reſidue 17 by 4, and the Remainder 1 ſhews it to be the Firſt after Leap-Year.

Julian Account, or *the Old Style.*

This Method of reckoning the Year, *viz.* making the common Year to conſiſt of 365 Days, and every fourth Year to have 366 Days, is now uſed in *Great-Britain* and *Ireland*, and ſome of the Northern Parts of *Europe*, and is called the *Julian Account*, or the *Old Style*. But the Time appointed by *Julius Cæſar* for the Length of a Solar Year is too much; for the Sun finiſhes his Courſe in the Ecliptic in 365 Days, 5 Hours and 49 Minutes, which is 11 Minutes leſs than the Civil Year; and therefore he again begins his Circuit 11 Minutes before the

Civil Year is ended; and ſo much being gained every Year, amounts in 131 Years, to a whole Day. So that if the Sun in any Year entered the Equinox upon the 20th of *March* at Noon, after the Space of 131 Years, he'll enter the ſame Point on the ſame Hour of the 19th of *March*. And therefore the Equinoxes will not always fall on the ſame Day of the Month, but by Degrees will move towards the Beginning of the Year.

At the Time of the *Council of Nice*, (when the Terms were ſettled for obſerving of *Eaſter*) the *Vernal Equinox* fell upon the 21ſt of *March*; but by its failing backwards 11 Minutes every Year, it was found that in *Anno* 1582, when the Kalendar was corrected, the Sun entered the Equinoctial Circle on the 11th of *March*, having departed ten whole Days from its former Place in the Year; and therefore Pope *Gregory* the XIIIth, deſigning to place the Equinoxes in their former Situation with reſpect to the Year, took theſe ten Days out of the Kalendar, and ordered that the eleventh of *March* ſhould be reckoned as the Twenty-firſt: And to prevent the Seaſons of the Year from going backwards for the future, he ordered that every hundredth Year, which in the *Julian* Form was to be a *Biſſextile*, ſhould be a common Year, and conſiſt only of 365 Days; but that being too much, every fourth Hundred was to remain *Biſſextile*. This Form of reckoning being eſtabliſhed by the Authority of Pope *Gregory* XIII. is called the *Gregorian Account*, or the *New Style*; and is obſerv'd in all the Countries where the Authority of the Pope is acknowledged, and likewiſe by ſeveral Nations of the reform'd Religion. There being now above a hundred Years paſt, ſince this Reformation was made in the Kalendar, the *Gregorian* Account has accordingly got before the *Julian* one Day more than it was in the Time of its Inſtitution, the Difference between theſe two Accounts being now eleven Days; ſo that the firſt Day of any Month, according to our Way of reckoning, is the 12th of the ſame Month according to the New Style.

Gregorian Account, or *New Style*.

I ſhall conclude this Section with a brief Account of the Atmoſphere.

The *Atmoſphere* is that thin Body of Air which ſurrounds the Earth, in which the Clouds hover, and by which in their Deſcent they are broke into Drops of Rain; which ſometimes according to the Warmth or Coldneſs of Air, are froze into *Snow*, or *Hailſtones*. *Thunder* and *Lightning* are alſo made in the *Atmoſphere*, and Wind is nothing elſe but a Percuſſion of the Air, occaſioned by its different Denſity in different Places. The Benefits we receive from the Atmoſphere are innumerable; without Air no earthly Creature could live, as is plainly proved by Experiments made by the *Air-*

Atmoſphere.

Pump;

Pump; and the Wholeſomeneſs of a Climate chiefly depends upon that of its Air: If there was no Atmoſphere to reflect the Rays of the Sun, no Part of the Heavens would be lucid and bright, but that wherein the Sun was placed; and if a Spectator ſhould turn his Back towards the Sun, he would immediately perceive it to be quite dark, and the leaſt Stars would be ſeen ſhining as they do in the cleareſt Night; and the Sun immediately before his ſetting would ſhine as briſk as at Noon, but in a Moment as ſoon as he got below the Horizon, the whole Hemiſphere of the Earth would be involved in as great a Darkneſs as if it were Midnight.

But by means of the Atmoſphere it happens, that while the Sun is above the Horizon, the whole Face of the Heavens is ſtrongly illuminated by its Rays, ſo as to obſcure the faint Light of the Stars, and render them inviſible; and after Sun-ſetting, though we receive no direct Light from him, yet we enjoy its reflected Light for ſome Time: For the Atmoſphere being higher than we are, is a longer Time before it is withdrawn from the Sun (as if a Man was to run up to the Top of a Steeple, he may ſee the Sun after it had been ſet to thoſe at the Bottom.) The Rays which the Atmoſphere receives from the Sun, after he is withdrawn from our Sight, are by Refraction faintly tranſmitted to us; until the Sun having got about 18 Degrees below the Horizon, he no longer enlightens our Atmoſphere, and then all that Part thereof which is over us becomes dark. After the ſame Manner in the Morning, when the Sun comes within 18 Degrees of our Horizon, he again begins to enlighten the Atmoſphere, and ſo more and more by Degrees, until he riſes and makes full Day.

This ſmall Illumination of the Atmoſphere, and State of the Heavens between Day and Night is called the *Twilight*, or the *Crepuſculum*.

Twilight, or *Crepuſculum.*

The Duration of Twilight is different in different Climates, and in the ſame Place, at different Times of the Year. The Beginning or ending of Twilight being accurately given, we may from thence eaſily find the Height of the Atmoſphere, which is not always the ſame. The mean Height of the Atmoſphere is computed to be about 40 Miles; but it is probable, the Air may expend itſelf a great deal further, there being properly no other Limits to it, as we can conceive, but as it continually decreaſes in Denſity the farther remote it is from the Earth, in a certain Ratio; which at laſt, as to our Conception, muſt in a Manner terminate.

SECT. II.

GEOGRAPHICAL DEFINITIONS.

Of the Situations of Places upon the Earth; of the different Situations of its Inhabitants; of Zones and Climates.

THE Situations of Places upon the Earth are determined by their Latitude and Longitude.

Latitude. 1. The *Latitude* of any Place (upon the Earth) is its neareſt Diſtance, either North or South, from the Equator; and if the Place be in the $\left\{\begin{array}{l}\text{Northern}\\ \text{Southern}\end{array}\right\}$ Hemiſphere, it is accordingly called $\left\{\begin{array}{l}\textit{North}\\ \textit{South}\end{array}\right\}$ *Latitude*; and is meaſured by an Arch of the Meridian intercepted betwixt the Zenith of the ſaid Place and the Equator. And all Places that lie on the ſame Side, and at the ſame Diſtance from the Equator, are ſaid to be in the ſame Parallel of Latitude: the Parallels of Latitude in *Geography*

phy being the ſame with the Parallels of Declination in *Aſtronomy*.

From this Definition ariſe the following Corollaries.

(1.) *That no Place can have above* 90 *Degrees of Latitude, either North or South.*

(2.) *Thoſe Places that lie under the Equinoctial (or thro' which the Equator paſſes) have no Latitude, it being from thence that the Calculation of Latitudes is counted; and thoſe Places that lie under the Poles have the greateſt Latitude, thoſe Points being at the greateſt Diſtance from the Equator.*

(3.) *The Latitude of any Place is always equal to the Elevation of the Pole in the ſame Place above the Horizon; and is therefore often expreſſed by the Pole's Height, or Elevation of the Pole; the Reaſon of which is, becauſe from the Equator to the Pole there is always the Diſtance of* 90 *Degrees, and from the Zenith to the Horizon the ſame Number of Degrees, each of theſe including the Diſtance from the Zenith to the Pole: That Diſtance therefore being taken away from both, will leave the Diſtance from the Zenith to the Equator, (which is the Latitude) equal to the Diſtance from the Pole to the Horizon.*

(4.) *The Elevation of the Equator in any Place is always equal to the Complement of the Latitude of the ſame Place.*

(5.) *A Ship ſailed directly* {*towards* / *from*} *the Equator* {*Leſſens* / *Augments*} *her Latitude, (or* {*Depreſſes* / *Raiſes*} *the Pole) juſt ſo much as is her Diſtance ſailed.*

Difference of Latitude. 2. *Difference of Latitude* is the neareſt Diſtance betwixt any two Parallels of Latitude, ſhewing how far the one is to the Northward or Southward of the other, which can never exceed 180 Degrees. And when the two Places are in the ſame Hemiſphere (or on the ſame Side of the Equator) the leſſer Latitude ſubtracted from the greater, and when they are on different Sides of the Equator, the two Latitudes added, gives the Difference of Latitude.

Longitude. 3. The *Longitude* of any Place (upon the Earth) is an Arch of the Equator, contain'd betwixt the Meridian of the given Place, and ſome fixed or known Meridian; or, it is equal to the Angle form'd by the two Meridians, which properly can never exceed 180 Degrees, tho' ſometimes the Longitude is counted Eaſterly quite round the Globe.

Since the Meridians are all moveable, and not one that can be fixed in the Heavens, (as the Equinoctial Circle is fixed, from whence the Latitudes of all Places are determined to be ſo much either North or South) the Longitudes of Places cannot ſo well be fixed from any other Meridian, but every Geographer is at his Liberty to make which he pleaſes his firſt Meridian, from whence to calculate the Longitudes of other Places. Hence it is that the Geographers of different Nations reckon their Longitudes from different Meridians, commonly chuſing the Meridian paſſing thro' the Metropolis of their own Country for their firſt: Thus, the *Engliſh* Geographers generally make the *Meridian* of *London* to be their firſt, the *French* that of *Paris*, and the *Dutch* that of *Amſterdam*, &c. and Mariners generally reckon the Longitude from the laſt known Land they ſaw. This arbitrary Way of reckoning the Longitude from different Places, makes it neceſſary, whenever we expreſs the Longitude of any Place, that the Place from whence it is counted be alſo expreſſed.

From the preceding Definitions ariſe the following Corollaries:

1. *If a Body ſhould ſteer directly North, or directly South, quite round the Globe, he'll continually change his Latitude; and paſs thro' the two Poles of the World, without deviating the leaſt from the Meridian of the Place he departed from; and conſequently at his Return will not differ in his Account of Time from the People reſiding in the ſaid Place.*

2. *If a Body ſhould ſteer round the Globe, either due Eaſt or due Weſt, he'll continually change his Longitude, but will go quite round without altering his Latitude; and if his Courſe ſhould be due Eaſt, he'll gain a Day compleatly in his Reckoning, or reckon one Day more than the Inhabitants of the Place from whence he departed; and if his Courſe had been Weſt, he would have loſt one Day, or reckon one leſs.*

The Reaſon of which is evident; for admitting our Traveller ſteers due Eaſt ſo many Miles in one Day as to make his Difference of Longitude equivalent to a Quarter of an Hour of Time, it is evident that the next Day the Sun will riſe to him a Quarter of an Hour ſooner than to the Inhabitants of the Place from whence he departed; and ſo daily, in Proportion to the Rate he travels, which in going quite round will make up one natural Day. In like Manner, if he ſteers due Weſt after the ſame Rate, he'll lengthen each Day a Quarter of an Hour, and conſequently the Sun will riſe to him ſo much later every Day; by which Means, in going quite round, he'll loſe one Day compleat in his Reckoning. From whence it follows,

3. *If two Bodies ſhould ſet out from the ſame Place, one ſteering Eaſt, and the other Weſt, and ſo continue their Courſes quite round, until they arrive at the Place from whence*

whence they ſet out, they'll differ two Days in their Reckoning at the Time of their Return.

4. *If a Body ſhould ſteer upon an Oblique Courſe (or any where betwixt the Meridian and the Eaſt or Weſt Points) he'll continually change both Latitude and Longitude, and that more or leſs, according to the Courſe he ſteers; and if he ſhould go quite round the Globe, he'll differ in his Account of Time, as by the ſecond Corol.*

5. *The People reſiding in the Eaſtermoſt of any two Places will reckon their Time ſo much the ſooner than thoſe who live in the other Place, according to the Difference of Longitude betwixt the two Places, allowing one Hour for every* 15 *Degrees,* &c. *and the contrary.*

II. *Of Zones and Climates,* &c.

Zones Torrid, Temperate, and *Frigid.*

4. *Zones* are large Tracts of the Surface of the Earth, diſtinguiſhed by the Tropicks and Polar Circles, being five in Number; *viz.* one *Torrid,* two *Temperate,* and two *Frigid.*

The *Torrid* or *Burning Zone* is all the Space comprehended between the two Tropicks; the Antients imagined this Tract of the Earth to be uninhabitable, becauſe of the exceſſive Heat, it being ſo near the Sun. All the Inhabitants of the Torrid Zone have the Sun in their Zenith, or exactly over their Heads twice in every Year; excepting thoſe who live exactly under the two Tropics, where the Sun comes to their Zenith only once in a Year.

The two *Temperate Zones* lie on either Side of the Globe, between the Tropics and the Polar Circles.

The two *Frigid Zones* are thoſe Spaces upon the Globe that are included within the two Polar Circles.

The Inhabitants of the Earth are alſo diſtinguiſhed by the Diverſity of their *Shadows.*

Amphiſcians.

Aſcians.

Thoſe who live in the Torrid Zone are called *Amphiſcians*, becauſe their Noon-Shadow is caſt different Ways, according as the Sun is to the Northward or Southward of their Zenith; but when the Sun is in their Zenith, they are called *Aſcians.*

Heteroſcians.

Aſcians Heteroſcians.

Periſcians.

The Inhabitants of the Temperate Zones are called *Heteroſcians*, becauſe their Noon-Shadow is always caſt the ſame Way: But thoſe who live under the Tropics are called *Aſcians Heteroſcians*; thoſe who live in the Frigid Zones are called *Periſcians*, becauſe ſometimes their Shadow is caſt round about them.

Theſe hard Names are only *Greek* Words, importing how the Sun caſts the Shadow of the ſeveral Inhabitants of the Earth; which would be a too trifling Diſtinction to be made here, was it not for the ſake of complying with Cuſtom.

The Inhabitants of the Earth are alſo diſtinguiſhed into three Sorts, in reſpect to their relative Situation to one another, and theſe are called the *Periœci*, *Antœci*, and *Antipodes*.

5. The *Periœci* are thoſe who live under opposite Points of the ſame Parallel of Latitude. They have their Seaſons of the Year at the ſame Time, and their Days and Nights always of the ſame Length with one another, but the one's *Noon* is the other's *Midnight*; and when the Sun is in the Equinoctial, he riſeth with the one when he ſets with the other. Thoſe who live under the Poles have no *Periœci*. *Periœci.*

6. The *Antœci* live under the ſame Meridian, and in the ſame Latitude, but on different Sides of the Equator; their Seaſons of the Year are contrary, and the Days of the one are equal to the Nights of the other, but the Hour of the Day and Night is the ſame with both; and when the Sun is in the Equinoctial, he riſes and ſets to both exactly at the ſame Time. Thoſe who live under the Equator have no *Antœci*. *Antœci.*

7. The *Antipodes* are thoſe who live diametrically oppoſite to one another, ſtanding, as it were, exactly Feet to Feet: Their Days and Nights, Summer and Winter, are at direct contrary Times. *Antipodes.*

The Surface of the Earth is by ſome diſtinguiſhed into *Climates*.

8. A

Climates. 8. A *Climate* is a Tract of the Surface of the Earth, included between two ſuch Parallels of Latitude, that the Length of the longeſt Day in the one exceeds that in the other by half an Hour.

The whole Surface of the Earth is conſidered, as being divided into 60 Climates, *viz.* from the Equator to each of the Polar Circles 24, ariſing from the Difference of ½ Hour in the Length of their longeſt Days; and from the Polar Circles to the Poles themſelves are ſix, ariſing from the Difference of an entire Month, the Sun being ſeen in the firſt of theſe a whole Month without ſetting; in the ſecond, two; and in the third, three Months, *&c.* Theſe Climates continually decreaſe in Breadth, the farther they are from the Equator. How they are framed, *viz* the Parallel of Latitude in which they end (that being likewiſe the Beginning of the next) with the reſpective Breadth of each of them, is ſhewed in the following Table:

A TA-

A TABLE *of the* CLIMATES.

CLIMATES *between the Equator and the Polar Circles.*

Climates.	*Longeſt Day.*	*Latitude.*		*Breadth.*		*Climates.*	*Longeſt Day.*	*Latitude.*		*Breadth.*	
		D.	*M.*	*D.*	*M.*			*D.*	*M.*	*D.*	*M.*
1	12 ½	8	25	8	25	13	18 ½	59	58	1	29
2	13	16	25	8	00	14	19	61	18	1	20
3	13 ½	23	50	7	25	15	19 ½	62	25	1	7
4	14	30	25	6	30	16	20	63	22	0	57
5	14 ½	36	28	6	8	17	20 ½	64	6	0	44
6	15	41	22	4	54	18	21	64	49	0	43
7	15 ½	45	29	4	7	19	21 ½	65	21	0	32
8	16	49	1	3	32	20	22	65	47	0	26
9	16 ½	51	58	2	57	21	22 ½	66	6	0	19
10	17	54	27	2	29	22	23	66	20	0	14
11	17 ½	56	37	2	10	23	23 ½	66	28	0	8
12	18	58	29	1	52	24	24	66	31	0	3

CLIMATES *between the Polar Circles and the Poles.*

Length of Day	*Latitude.*		*Length of Days.*	*Latitude.*	
Months.	*D.*	*M.*	*Months.*	*D.*	*M.*
1	67	21	4	78	30
2	69	48	5	84	5
3	73	37	6	00	00

III. *Of*

III. *Of the Poetical Riſing and Setting of the Stars.*

Coſmical, Acronical. and *Heliacal Riſing* and *Setting.*

The Ancient Poets make frequent Mention of the Stars Riſing and Setting, either *Coſmically*, *Acronically*, or *Heliacally*; whence theſe Diſtinctions are called *Poetical.*

A Star is ſaid to *riſe* or *ſet Coſmically*, when it riſes or ſets at Sun-riſing; and when it *riſes* or *ſets* at Sun-ſetting, it is ſaid to riſe or ſet *Acronically*. A Star *riſes Heliacally* when firſt it becomes viſible, after it had been ſo near the Sun as to be hid by the Splendor of his Rays: And a Star is ſaid to *ſet Heliacally*, when it is firſt immerſed, or hid by the Sun's Rays.

The *Fixed Stars*, and the three ſuperior Planets, *Mars*, *Jupiter*, and *Saturn*, riſe *Heliacally* in the Morning; but the Moon riſes *Heliacally* in the Evening, becauſe the Sun is ſwifter than the ſuperior Planets, and ſlower than the Moon.

IV. *Of the Surface of the Earth, conſidered as it is compoſed of Land and Water.*

The Earth conſiſts naturally of two Parts, Land and Water, and therefore it is called the *Terraqueous Globe.* Each of theſe Elements is ſubdivided into various Forms and Parts, which accordingly are diſtinguiſhed by different Names.

I. *Of the Land.*

The Land is diſtinguiſhed into *Continents*, *Iſlands*, *Peninſula's*, *Iſthmus's*, *Promontories*, *Mountains*, or *Coaſts*.

Continent. 9. A *Continent* is a large Quantity of Land, in which many great Countries are joined together, without being ſeparated from each other by the Sea: Such are *Europe*, *Aſia*, *Africa*, and the vaſt Continent of *America*; which four are the principal Diviſions of the Earth. A Continent is ſometimes called the *Main Land*. *Main Land*

Iſland. 10. An *Iſland* is a Country, or Portion of Land, environ'd round with Water: Such are *Great-Britain* and *Ireland*; *Sardinia*, *Sicily*, &c. in the *Mediterranean Sea*; the *Iſles of Wight*, *Angleſey*, &c. near *England*. Alſo a ſmall Part of dry Land, in the Midſt of a River, is called an Iſland. Sometimes a large Iſland, when compared to a leſſer, is called the Continent; as if we compare the *Iſle of Wight* to *England*, the latter may be properly called the Continent.

Peninſula. 11. A *Peninſula* is a Part of Land almoſt environ'd with Water, ſave one narrow Neck adjoining it to the Continent; or which is almoſt an Iſland: Such is *Den-*

mark joining to *Germany*; alſo *Africa* is properly a large Peninſula joining to *Aſia*.

Iſthmus. 12. An *Iſthmus* is a narrow Neck of Land joining a Peninſula to the Continent; as the *Iſthmus* of *Sues*, which joins *Africa* to *Aſia*; that of *Panama* joining North and South *America*, &c.

Promontory. 13. A *Promontory* is a high Part of Land ſtretching out into the Sea, and is often call'd a *Cape*, or *Headland*: Such is the *Cape of Good Hope* in the South of *Africa*; *Cape Finiſtre* on the Weſt of *Spain*; alſo the *Lizard Point*, and the *Land's End*, are two Capes or Headlands on the Weſt of *England*. *Mountain.* A *Mountain* is a high Part of Land in the Midſt of a Country, over-topping the adjacent Parts.

A Coaſt or Shore. 14. A *Coaſt* or *Shore* is that Part of Land which borders upon the Sea, whether it be in Iſlands or a Continent: And that Part of the Land which is far diſtant from the Sea, *Inland.* is called the *Inland Country*. Theſe are the uſual Diſtinctions of the Land.

The Water is diſtinguiſhed into *Oceans*, *Seas*, *Lakes*, *Gulfs*, *Straits*, and *Rivers*.

The Ocean, or Main Sea. 15. The *Ocean*, or *Main Sea*, is a vaſt ſpreading Collection of Water, not divided or ſeparated by Lands running between: Such is the *Atlantic* or *Weſtern Ocean*, between *Europe* and *America*, the *Pacific Ocean*, or *South-Sea*, &c.

Note, Thoſe Parts of the Ocean which border upon the Land, are called by various Names, according to thoſe of the adjacent Countries; as, the *Britiſh Sea*, the *Iriſh Sea*, the *French* and *Spaniſh Sea*.

16. A *Lake* is a Collection of deep ſtanding Water, incloſed all round with Land, and not having any viſible and open Communication with the Sea: But when this Lake is very large, it is commonly called a Sea; as, the *Caſpian Sea* in *Aſia*, &c. *A Lake.*

17. A *Gulf* is a Part of the Sea almoſt encompaſſed with Land, or that which runs up a great Way into the Land; as, the *Gulf of Venice*, &c. But if it be very large, 'tis rather called an *Inland Sea*; as, the *Baltick Sea*, the *Mediterranean Sea*, the *Red Sea*, or the *Arabian Gulf*, &c. And a ſmall Part of the Sea thus environed with Land is uſually called a *Bay*. If it be but a very ſmall Part, or, as it were, a ſmall Arm of the Sea, that runs but a few Miles between the Land, it is called a *Creek* or *Haven*. *A Gulf.* *Creek* or *Haven.*

18. A *Strait* is a narrow Paſſage lying between two Shores, whereby two Seas are joined together; as, the *Straits of Dover*, between the *Britiſh Channel* and the *German Sea*; the *Straits of Gibraltar*, between the *Atlantick* and the *Mediterranean Sea*. The *Mediterranean* itſelf is alſo ſometimes called the *Straits*. *A Strait.*

Theſe are all the neceſſary Terms commonly uſed in *Geography*. The Names of the ſeveral Countries, Seas, and all the principal Diviſions of the Earth, the Reader will find expreſſed upon the Terreſtrial Globes. To give a tolerable Account of the Produce of each Country, the Genius of the People, their political Inſtitutions, *&c.* is properly a particular Subject of itſelf, and quite foreign to our Deſign. We ſhall next proceed to the Uſe of the Globes; but firſt it may not be amiſs to take a ſhort *Review* of their Appurtenances.

Thoſe Circles of the Sphere that are *fixed*, are (as has been already ſaid) drawn upon the *Globes* themſelves; thoſe that are *moveable*, are ſupplied by the *Braſs Meridian*, the *Wooden Horizon*, and the *Quadrant of Altitude*.

Braſs Meridian.

1. That Side of the *Brazen Meridian*, which is divided into Degrees, repreſents the *true Meridian*; this Side is commonly turned towards the Eaſt, and 'tis uſual to place the Globe ſo before you, that the North be to the Right-hand, and the South to the Left, The Meridian is divided into 4 Quadrants, each being 90 Degrees, two of which are numbered from that Part of the Equinoctial, which is above the Horizon, towards each of the Poles; the other two Quadrants are numbered from the Poles towards the Equator. The Reaſon why two

Quadrants of the Meridian are numbered from the Equator, and the other two from the Poles, is, becauſe the former of theſe two ſerve to ſhew the Diſtance of any Point on the Globe from the Equator, and the other to elevate the Globe to the Latitude of the Place.

Wooden Horizon.

2. The upper Side of the Wooden Frame, called the *Wooden Horizon*, repreſents the true Horizon; the Circles drawn upon this Plane have been already deſcribed; we may obſerve, that the firſt Point of ♈ is the Eaſt, and the oppoſite being the firſt Point of ♎ is the Weſt, the Meridian paſſing through the North and South Points.

Quadrant of Altitude.

3. The *Quadrant of Altitude* is a flexible Plate of thin Braſs, having a Nut and Screw at one End, to be faſtened to the Meridian of either Globe, as Occaſion requires. The Edge of this Quadrant, which has the Graduations upon it, called the fiducial Edge, is that which is always meant whenever we make mention of the Quadrant of Altitude.

Hour-Circle.

4. The *Horary* or *Hour-Circle* is divided into twice twelve Hours, the two XII's coinciding with the Meridian; the uppermoſt XII is that at *Noon*, and the lowermoſt twards the Horizon is XII at *Night*. The Hours on the *Eaſt* Side of the Meridian are the *Morning Hours*, and thoſe on the *Weſt* Side the *Hours after Noon*. The Axis

of the Globe carries round the *Hand* or *Index* which points the Hour, and paſſes through the Center of the Hour-Circle.

The Things above deſcribed are common to both Globes; but there are ſome others which are peculiar or proper to one Sort of Globe. The two *Colures*, and the *Circles* of *Latitude*, from the Ecliptic, belong only to the *Celeſtial Globes*; alſo the Ecliptic itſelf does properly belong only to this Globe, tho' it is always drawn on the Terreſtrial, for the ſake of thoſe that might not have the other Globe by them. The Equinoctial on the Celeſtial Globe is always numbered into 360 Degrees, beginning at the Equinoctial Point ♈; but on the Terreſtrial, it is arbitrary where theſe Numbers commence, according to the Meridian of what Place you intend for your firſt; and the Degrees may be counted either quite round to 360, or both Ways, till they meet in the oppoſite Part of the Meridian at 180.

SECT. III.

The USE *of the* GLOBES.

PROBLEM I, *To find the Latitude and Longitude of any given Place upon the Globe; and on the contrary, the Latitude and Longitude being given, to find the Place.*

1. TURN the Globe round its Axis, till the given Place lies exactly under the (Eaſtern Side of the Braſs) Meridian, then that Degree upon the Meridian, which is directly over it, is the *Latitude*; which is accordingly North or South, as it lies in the Northern or Southern Hemiſphere, the Globe remaining in the ſame Poſition.

That Degree upon the Equator, which is cut by the Brazen Meridian, is the *Longitude* required from the firſt Meridian upon the Globe. If the Longitude is counted both Ways from the firſt Meridian upon the Globe, then we are to conſider, whether the given Place lies Eaſterly or Weſterly from the firſt Meridian, and the Longitude muſt be expreſſed accordingly.

The *Latitudes* of the following Places; and upon a Globe where the Longitude is reckon'd both Ways from the Meridian of *London*, their Longitudes will be found as follow:

	Latitude.		*Longitude.*	
	Deg.		Deg.	
Rome	41 ¼	North.	13	Eaſt.
Paris	48 ¾	N.	2 ¼	E.
Mexico	20	N.	102	W.
Cape Horn	58	S.	80	W.

2. *The Latitude and Longitude being given, to find the Place.*

Seek for the given Longitude in the Equator, and bring that Point to the Meridian; then count from the Equator on the Meridian the Degree of Latitude given, towards the Arctic and Antarctic Pole, according as the Latitude is Northerly or Southerly, and under that Degree of Latitude lies the *Place* required.

PROB. II. *To find the Difference of Latitude betwixt any two given Places.*

Bring each of the Places propoſed ſucceſſively to the Meridian, and obſerve where they interſect it, then the Number of Degrees upon the Meridian, contained between the two Interſections will be the *Difference of Latitude* required. Or, if the Places propoſed are on the ſame Side of the Equator, having firſt found their Latitudes, ſubtract the leſſer from the greater; but if they are on the contrary Sides of the Equator, add them both together, and the Difference in the firſt Caſe, and the Sum in the latter, will be the Difference of Latitude required.

Thus the Difference of Latitude betwixt *London* and *Rome* will be found to be 9 $\frac{3}{4}$ Degrees; betwixt *Paris* and *Cape Bona Eſperance* 83 Degrees.

PROB. III. *To find the Difference of Longitude betwixt any two given Places.*

Bring each of the given Places ſucceſſively to the Meridian, and ſee where the Meridian cuts the Equator each Time; the Number of Degrees contained betwixt thoſe two Points, if it be leſs than 180 Degrees, otherwiſe the Remainder to 360 Degrees will be the Difference of *Longitude* required. Or,

Having brought one of the given Places to the Meridian, bring the Index of the Hour-Circle to 12 o'Clock; then having brought the other Place to the Meridian, the Number of Hours contained between the Place the Index was firſt ſet at, and the Place where it now points, is the Difference of Longitude in Time betwixt the two Places.

Thus the Difference of Longitude betwixt *Rome* and *Conſtantinople* will be found to be 19 Degrees, or 1 Hour and a Quarter; betwixt *Mexico* and *Pekin* in *China*, 140 Degrees, or 9 $\frac{1}{3}$ Hours.

PROB. IV. *Any Place being given to find all thoſe Places that are in the ſame Latitude with the ſaid Place.*

The Latitude of the given Place being marked upon the Meridian, turn the Globe round its Axis, and all thoſe Places that paſs under the ſame Mark are in the ſame Latitude with the given Place, and have their Days and Nights of equal Lengths. And when any Place is brought to the Meridian, all the Inhabitants that lie under the upper Semicircle of it, have their Noon or Midday at the ſame Point of abſolute Time exactly.

PROB. V. *The Day of the Month being given; to find the Sun's Place in the Ecliptic, and his Declination.*

1. *To find the Sun's Place:* Look for the Day of the Month given in the Kalendar of Months upon the Horizon, and right againſt it you'll find that Sign and Degree of the

Ecliptic which the Sun is in. The Sun's Place being thus found, look for the ſame in the Ecliptic Line which is drawn upon the Globe, and bring that Point to the Meridian, then that Degree of the Meridian, which is directly over the Sun's Place, is the *Declination* required; which is accordingly either North or South, as the Sun is in the Northern or Southern Signs. Thus,

	Sun's Place.			*Declination.*		
		Deg.	Min.	Deg.	Min.	
April 23	♉	3	00	12	32	N.
July 31	♌	7	51	18	20	N.
October 26	♏	2	49	12	28	S.
January 20	♒	0	17	20	07	S.

PROB. VI. *To rectify the Globe for the Latitude, Zenith, and the Sun's Place.*

1. *For the Latitude:* If the Place be in the Northern Hemiſphere, raiſe the Arctic Pole above the Horizon; but for the South Latitude you muſt raiſe the Antarctic; then move the Meridian up and down in the Notches, until the Degrees of the Latitude counted upon the Meridian below the Pole, cuts the Horizon, and then the Globe is adjuſted to the Latitude.

2. *To rectify the Globe for the Zenith:* Having elevated the Globe according to the Latitude, count the Degrees thereof upon

the Meridian from the Equator towards the elevated Pole, and that Point will be the Zenith or the Vertex of the Place; to this Point of the Meridian faſten the Quadrant of Altitude, ſo that the graduated Edge thereof may be joined to the ſaid Point.

3. Bring the Sun's Place in the Ecliptic to the Meridian, and then ſet the Hour-Index to XII at Noon, and the Globe will be rectified *to the Sun's Place.*

If you have a little Mariner's Compaſs, the Meridian of the Globe may be eaſily ſet to the Meridian of the Place.

PROB. VII. *To find the Diſtance between any two given Places upon the Globe, and to find all thoſe Places upon the Globe that are at the ſame Diſtance from a given Place.*

Lay the Quadrant of Altitude over both the Places, and the Number of Degrees intercepted between them being reduced into Miles, will be the Diſtance required: Or, you may take the Diſtance betwixt the two Places with a Pair of Compaſſes, and applying that Extent to the Equator, you'll have the Degrees of Diſtance as before.

Note, A *Geographical Mile* is the $\frac{1}{60}$th Part of a Degree; wherefore if you multiply the Number of Degrees by 60, the Product will be the Number of Geographical

Miles of Diſtance ſought; but to reduce the ſame into *Engliſh* Miles, you muſt multiply by 70, becauſe about 70 *Engliſh* Miles make a Degree of a great Circle upon the Superficies of the Earth.

Thus, the Diſtance betwixt *London* and *Rome* will be found to be about 13 Degrees, which is 780 Geographical Miles.

If you rectify the Globe for the Latitude and Zenith of any given Place, and bring the ſaid Place to the Meridian; then turning the Quadrant of Altitude about, all thoſe Places that are cut by the ſame Point of it are at the ſame Diſtance from the given Place.

PROB. VIII. *To find the Angle of Poſition of Places, or the Angle formed by the Meridian of one Place, and a great Circle paſſing through both the Places.*

Having rectified the Globe for the Latitude and Zenith of one of the given Places, bring the ſaid Place to the Meridian, then turn the Quadrant of Altitude about, until the fiducial Edge thereof cuts the other Place, and the Number of Degrees upon the Horizon, contained between the ſaid Edge and the Meridian, will be the Angle of Poſition ſought.

Thus, the Angle of Poſition at the *Lizard*, between the Meridian of the *Lizard* and the Great Circle, paſſing from thence to *Barbadoes* is 69 Degrees South-Weſterly; but the Angle of Poſition between the ſame Places at *Barbadoes,* is but 38 Degrees North-Eaſterly.

SCHOLIUM.

The Angle of Poſition between two Places is a different Thing from what is meant by the Bearings of Places; the *Bearings* of two Places is determined by a Sort of ſpiral Line, called a *Rhumb Line*, paſſing between them in ſuch a Manner, as to make the ſame or equal Angles with all the Meridians through which it paſſeth; but the *Angle* or *Poſition* is the very ſame Thing with what we call the Azimuth in Aſtronomy, both being formed by the Meridian and a great Circle paſſing thro' the Zenith of a given Place, and a given Point either in the Heavens, then called the Azimuth, or upon the Earth, then called the Angle of Poſition.

From hence may be ſhewed the Error of that Geographical Paradox, *viz.* If a Place A bears from another B due Weſt, B ſhall not bear from A due Eaſt. I find this Paradox vindicated by an Author, who at the ſame Time gives a true Definition of a Rhumb Line: But his Arguments are ungeometrical; for if it be admitted that the

Eaſt and Weſt Lines make the ſame Angles with all the Meridians through which they paſs, it will follow that theſe Lines are the Parallels of Latitude: For any Parallel of Latitude is the Continuation of the Surface of a *Cone*, whoſe Sides are the Radii of the Sphere, and Circumference of its Baſe the ſaid Parallel; and it is evident, that all the Meridians cut the ſaid Surface at right (and therefore at equal) Angles; whence it follows, that the Rhumbs of Eaſt and Weſt are the Parallels of Latitude, though the Caſe may ſeem different, when we draw inclining Lines (like Meridians) upon Paper, without carrying our Ideas any farther.

PROB. IX. *To find the* Antœci, Periœci, *and* Antipodes *to any given Place.*

Bring the given Place to the Meridian, and having found its Latitude, count the ſame Number of Degrees on the Meridian from the Equator towards the contrary Pole, and that will give the Place of the *Antœci*. The Globe being ſtill in the ſame Poſition, ſet the Hour Index to XII at Noon, then turn the Globe about till the Index points to the lower XII; the Place which then lies under the Meridian, having the ſame Latitude with the given Place, is the *Periœci* required. As the Globe now ſtands, the *An-*

Antipodes of the given Place are under the ſame Point of the Meridian, that its *Antœci* ſtood before: Or, if you reckon 180 Degrees upon the Meridian from the given Place, that Point will be the *Antipodes.*

Let the given Place be *London* in the Latitude of 51½ Degrees North, that Place which lies under the ſame Meridian and in the Latitude 51½ Degrees South, is the *Antœci*; that which lies in the ſame Parallel with *London,* and 180 Degrees of Longitude from it, is the *Periœci*; and the *Antipodes* is that Place whoſe Longitude from *London* is 180 Degrees, and Latitude 51½ Degrees South.

PROB. X. *The Hour of the Day at one Place being given; to find the correſpondent Hour (or what o'Clock it is at that Time) in any other Place.*

The Difference of Time betwixt two Places is the ſame with their Difference of Longitude; wherefore having found their Difference of Longitude, reduce it into Time, (by allowing one Hour for every 15 Degrees, *&c.*) and if the Place where the Hour is required lies $\left\{\begin{array}{l}\text{Eaſterly,}\\ \text{Weſterly,}\end{array}\right\}$ from the Place where the Hour is given, $\left\{\begin{array}{l}\text{Add}\\ \text{Subtract}\end{array}\right\}$ the Difference of Longitude reduced into Time {to / from} the Hour given; and the Sum or Remainder will accordingly be the Hour required. Or,

Having brought the Place at which the Hour is given to the Meridian, ſet the Hour Index to the given Hour; then turn the Globe about until the Place where the Hour is required comes to the Meridian, and the Index will point out the Hour at the ſaid Place.

Thus when it is *Noon* at *London*, it is

		H.	M.	
At	*Rome* ——— ———	0	52	P. M.
	Conſtantinople ——— —	2	07	P. M.
	Vera-Cruz ——— —	5	30	A. M.
	Pequin in *China* ———	7	50	P. M.

PROB. XI. *The Day of the Month being given, to find thoſe Places on the Globe where the Sun will be Vertical, or in the Zenith, that Day.*

Having found the Sun's Place in the Ecliptic, bring the ſame to the Meridian, and note the Degree over it; then turning the Globe round, all Places that paſs under that Degree will have the Sun vertical that Day.

Prob. XII. *A Place being given in the* Torrid Zone, *to find thoſe two Days in which the Sun ſhall be Vertical to the ſame.*

Bring the given Place to the Meridian, and mark what Degree of Latitude is exactly over it; then turning the Globe about its Axis, thoſe two Points of the Ecliptic, which paſs exactly under the ſaid Mark, are the Sun's Place; againſt which, upon the Wooden Horizon, you'll have the Days required.

Prob. XIII. *To find where the Sun is Vertical at any given Time aſſign'd; or the Day of the Month and the Hour at any Place (ſuppoſe* London*) being given, to find in what Place the Sun is Vertical at that very Time.*

Having found the Sun's Declination, and brought the firſt Place *(London)* to the Meridian, ſet the Index to the given Hour, then turn the Globe about until the Index points to XII at Noon; which being done, that Place upon the Globe which ſtands under the Point of the Sun's Declination upon the Meridian, has the Sun that Moment in the Zenith.

PROB. XIV. *The Day, and the Hour of the Day at one Place, being given; to find all thoſe Places upon the Earth, where the Sun is then Riſing, Setting, Culminating (or on the Meridian) alſo where it is Day-light, Twilight, Dark Night, Midnight; where the Twilight then begins, and where it ends; the Height of the Sun in any Part of the illuminated Hemiſphere; alſo his Depreſſion in the obſcure Hemiſphere.*

Having found the Place where the Sun is Vertical at the given Hour, rectify the Globe for that Latitude, and bring the ſaid Place to the Meridian.

Then all thoſe Places that are in the Weſtern Semicircle of the Horizon, have the Sun riſing at that Time.

Thoſe in the Eaſtern Semicircle have it ſetting.

To thoſe who live under the upper Semicircle of the Meridian, it is 12 o'Clock at Noon. And,

Thoſe who live under the lower Semicircle of the Meridian have it at Midnight.

All thoſe Places that are above the Horizon, have the Sun above them, juſt ſo much as the Places themſelves are diſtant from the Horizon; which Height may be known by fixing the Quadrant of Altitude in the Zenith, and laying it over any particular Place.

In all thoſe Places that are 18 Degrees below the Weſtern Side of the Horizon, the Twilight is juſt beginning in the Morning, or the Day breaks. And in all thoſe Places that are 18 Degrees below the Eaſtern Side of the Horizon, the Twilight is ending, and the total Darkneſs beginning.

The Twilight is in all thoſe Places whoſe Depreſſion below the Horizon does not exceed 18 Degrees. And

All thoſe Places that are lower than 18 Degrees have dark Night.

The Depreſſion of any Place below the Horizon is equal to the Altitude of its *Antipodes*, which may be eaſily found by the Quadrant of Altitude.

PROB. XV. *The Day of the Month being given; to ſhew, at one View, the Length of Day and Night in all Places upon the Earth at that Time; and to explain how the Viciſſitudes of Day and Night are really made by the Motion of the Earth round her Axis in 24 Hours, the Sun ſtanding ſtill.*

The Sun always illuminates one half of the Globe, or that Hemiſphere which is next towards him, while the other remains in Darkneſs: And if (as by the laſt Problem) we elevate the Globe according to the Sun's Place in the Ecliptic, it is evident, that the Sun (he being at an immenſe Diſtance from the Earth) illuminates all that Hemiſphere, which is above the Horizon; the Wooden Horizon itſelf will be the Circle terminating Light and Darkneſs; and all thoſe Places that are below it, are wholly deprived of the Solar Light.

The Globe ſtanding in this Poſition, thoſe Arches of the Parallels of Latitude which ſtand above the Horizon, are the *Diurnal Arches*, or the Length of the Day in all thoſe Latitudes at that Time of the Year; and the remaining Parts of thoſe Parallels, which are below the Horizon, are the *Nocturnal Arches*, or the Length of the Night in thoſe Places. The Length of the Diurnal Arches may be found by counting how many Hours are contained between the two Meridians, cutting any Parallel of Latitude, in the Eaſtern and Weſtern Parts of the Horizon.

In all thoſe Places that are in the Weſtern Semicircle of the Horizon, the Sun appears riſing: For the Sun, ſtanding ſtill in the Vertex, (or above the Braſs Meridian) appears Eaſterly, and 90 Degrees diſtant from all thoſe Places that are in the Weſtern Semicircle of the Horizon; and therefore in thoſe Places he is then riſing. Now, if we pitch upon any particular Place upon the Globe, and bring it to the Meridian, and then bring the Hour-Index to the lower 12, which in this Caſe we'll ſuppoſe to be 12 at Noon; (becauſe otherwiſe the Numbers upon the Hour Circle will not anſwer our Purpoſe) and afterwards turn the Globe about, until the aforeſaid Place be brought to the Weſtern Side of the Horizon; the Index will then ſhew the Time of Sun-riſing in that Place. Then turn the Globe gradually about from Weſt to Eaſt, and minding the Hour-Index, we ſhall ſee the Progreſs made in the Day every Hour, in all Latitudes upon the Globe, by the real Motion of the Earth round its Axis; until, by their continual Approach to the Braſs Meridian (over which the Sun ſtands ſtill all the while) they at laſt have Noon Day, and the Sun appears at the higheſt; and then by Degrees, as they move Eaſterly, the Sun ſeems to decline Weſtward, until, as the Places ſucceſſively arrive in the Eaſtern Part of the Horizon, the Sun appears to ſet in the Weſtern: For the Places that are in the Horizon, are 90 Degrees diſtant from the Sun. We may obſerve, that all Places upon the Earth, that differ in Latitude, have their Days of different Length (except when the Sun is in the Equinoctial) being longer or ſhorter, in proportion to what Part of the Parallels ſtand above the Horizon.

Thoſe that are in the ſame Latitude, have their Days of the ſame Length; but have them commence ſooner or later, according as the Places differ in Longitude.

PROB. XVI, *To explain in general the Alteration of Seaſons, or Length of the Days and Nights, made in all Places of the World, by the Sun's (or the Earth's) annual Motion in the Ecliptic.*

It has been ſhewed in the laſt Problem, how to place the Globe in ſuch a Poſition, as to exhibit the Length of the Diurnal and Nocturnal Arches in all Places of the Earth, at a particular Time: If the Globe be continually rectified, according as the Sun alters his Declination (which may be known by bringing each Degree of the Ecliptic ſucceſſively to the Meridian) you'll ſee the gradual Increaſe or Decreaſe made in the Days in all Places of the World, according as a greater or leſſer Portion of the Parallels of Latitude ſtand above the Horizon. We ſhall illuſtrate this Problem by Examples taken at different Times of the Year.

1. Let the Sun be in the firſt Point of ♋ (which happens on the 21ſt of *June*) that Point being brought to the Meridian, will ſhew the Sun's Declination to be 23 ½ De-

grees North; then the Globe muſt be rectified to the Latitude of 23½ Degrees; and for the better Illuſtration of the Problem, let the firſt Meridian upon the Globe be brought under the Braſs Meridian. The Globe being in this Poſition you'll ſee at one View the Length of the Days in all Latitudes, by counting the Number of Hours contained between the two extreme Meridians, cutting any particular Parallel you pitch upon, in the Eaſtern and Weſtern Part of the Horizon. And you may obſerve that the lower Part of the Arctic Circle juſt touches the Horizon, and conſequently all the People who live in that Latitude have the Sun above their Horizon for the Space of 24 Hours, without ſetting; only when he is in the lower Part of the Meridian (which they would call 12 at Night) he juſt touches the Horizon.

To all thoſe who live between the Arctic Circle and the Pole, the Sun does not ſet, and its Height above the Horizon, when he is in the lower Part of the Meridian, is equal to their Diſtance from the Arctic Circle: For Example, Thoſe who live in the 83d Parallel have the Sun when he is loweſt at this Time 13½ Degrees high.

If we caſt our Eye Southward, towards the Equator, we ſhall find, that the Diurnal Arches, or the Length of the Days in the ſeveral Latitudes, gradually leſſen: The Diurnal Arch of the Parallel of *London* at this Time is 16½ Hours; that of the *Equator* (is always) 12 Hours; and ſo continually leſs, till we come to the *Antarctic Circle*, the upper Part of which juſt touches the Horizon; and thoſe who live in this Latitude have juſt one Sight of the Sun, peeping as it were in the Horizon: And in all that Space between the Antarctic Circle and the South Pole, lies in total Darkneſs.

If from this Poſition we gradually move the Meridian of the Globe. according to the progreſſive Alterations made in the Sun's Declination, by his Motion in the Ecliptic, we ſhall find the Diurnal Arches of all thoſe Parallels, that are on the Northern Side of the Equator, continually decreaſe; and thoſe on the Southern Side continually increaſe, in the ſame Manner as the Days in thoſe Places ſhorten and lengthen. Let us again obſerve the Globe when the Sun has got within 10 Degrees of the Equinoctial; now the lower Part of the 80th Parallel of North Latitude juſt touches the Horizon, and all the Space betwixt this and the Pole, falls in the illuminated Hemiſphere; but all thoſe Parallels that lie betwixt this and the Arctic Circle, which before were wholly above the Horizon, do now interſect it, and the Sun appears to them to riſe and ſet. From hence to the Equator, we ſhall find that the Days have gradually ſhortned; and from the Equator Southward, they have gradually lengthened, until we come to the 80th Parallel of South Latitude; the upper Part of which juſt touches the Horizon, and all Places betwixt this and the South Pole are in total Darkneſs; but thoſe Parallels betwixt this and the Antarctic Circle, which before were wholly upon the Horizon, are now partly above it; the Length of their Days being exactly equal to that of the Nights in the ſame Latitude in the contrary Hemiſphere. This alſo holds univerſally, that the Length of the Day in one Latitude North, is exactly equal to the Length of the Night in the ſame Latitude South; and *vice verſa.*

Let us again follow the Motion of the Sun, until he has got into the Equinoctial, and take a View of the Globe while it is in this Poſition. Now all the Parallels of Latitude are cut into two equal Parts by the Horizon, and conſequently the Days and Nights are of equal Lengths, *viz.* 12 Hours each in all Places of the World; the Sun riſing and ſetting at Six o'Clock, excepting under the two *Poles,* which now lie exactly in the Horizon: Here the Sun ſeems to ſtand ſtill in the ſame Point of the Heavens for ſome Time, until by Degrees, by his Motion in the Ecliptic, he aſcends higher to one and diſappears to the other, there being properly no Days and Nights under the Poles; for there the Motion of the Earth round its Axis can't be obſerved.

If we follow the Motion of the Sun towards the Southern Tropic we ſhall ſee the Diurnal Arches of the Northern Parallels continually decreaſe, and the Southern ones iucreaſe in the ſame Proportion according to their reſpective Latitudes; the North Pole continually deſcending, and the South Pole aſcending above the Horizon, until the Sun arrives into ♑, at which Time all the Space within the Antarctic Circle is above the Horizon; while the Space between the Arctic Circle, and its neighbouring Pole, is in total Darkneſs. And we ſhall now find all other Circumſtances quite reverſe to what they were when the Sun was in ♋; the Nights now all over the World being of the ſame Length that the Days were of before.

We have now got to the Extremity of the Sun's Declination; and if we follow him through the other half of the Ecliptic, and rectify the Globe accordingly, we ſhall find the Seaſons return in their Order, until at length we bring the Globe into its firſt Poſition.

The two foregoing Problems were not, as I know of, publiſhed in any Book on this Subject before; and I have dwelt the longer upon them, becauſe they very well illuſtrate how the Viciſſitudes of Days and Nights are made all over the World by the Motion of the Earth round her Axis; the Horizon of the Globe being made the Circle, ſeparating Light and Darkneſs, and ſo the Sun to ſtand ſtill in the Vertex. And if we really could move the Meridian, according to the Change of the Sun's Declination, we ſhould ſee at one View the continual Change made in the Length of Days and Nights, in all Places on the Earth; but as Globes are fitted up, this cannot be done; neither are they adapted for the common Purpoſes, in Places near the Equator, or any where in the Southern Hemiſphere. But this Inconvenience is now remedied (at a ſmall additional Expence) by the Hour Circle being made to ſhift to either Pole; and ſome Globes are now made with an Hour Circle fixt to the Globe at each Pole, between the Globe and Meridian, ſo as to have none without Side to interrupt the Meridian from moving quite round the Wooden Horizon.

PROB. XVII. *To ſhew by the Globe, at one View, the Length of the Days and Nights in any particular Places, at all Times of the Year.*

Becauſe the Sun, by his Motion in the Ecliptic, alters his Declination a ſmall Matter every Day; if we ſuppoſe all the Torrid Zone to be filled up with a ſpiral Line, having ſo many Turnings; or a Screw having ſo many Threads, as the Sun is Days in going from one Tropic to the other: And theſe Threads at the ſame Diſtance from one another in all Places, as the Sun alters his Declination in one Day in all thoſe Places reſpectively: This Spiral Line or Screw will repreſent the apparent Paths deſcribed by the Sun round the Earth every Day; and by following the Thread from one Tropic to the other, and back again, we ſhall have the Path the Sun ſeems to deſcribe round the Earth in a Year. But becauſe the Inclinations of theſe Threads to one another are but ſmall, we may ſuppoſe each Diurnal Path to be one of the Parallels of Latitude drawn, or ſuppoſed to be drawn upon the Globe. Thus much being premiſed, we ſhall explain this *Problem*, by placing the Globe according to ſome of the moſt remarkable Poſitions of it, as before we did for the moſt remarkable Seaſons of the Year.

In the preceding Problem, the Globe being rectified according to the Sun's Declination, the upper Parts of the Parallels of Latitude, repreſented the *Diurnal Arches*, or the Length of the Days all over the World at that particular Time: Here we are to rectify the Globe according to the Latitude of the Place, and then the upper Parts of the Parallels of Declination are the Diurnal Arches; and the Length of the Days at all Times of the Year, may be here determined by finding the Number of Hours contained between the two extreme Meridians, which cut any Parallel of Declination, in the Eaſtern and Weſtern Points of the Horizon; after the after the ſame Manner, as before we found the Length of the Day in the ſeveral Latitudes at a particular Time of the Year.

1. Let the Place propoſed be under the Equinoctial, and let the Globe be accordingly rectified for 00 Degrees of Latitude, which is called a direct Poſition of the Sphere. Here all the Parallels of Latitude, which in this Caſe we'll call the Parallels of Declination, are cut by the Horizon into two equal Parts; and conſequently thoſe who live under the Equinoctial, have the Days and Nights of the ſame Length at all Times of the Year; alſo in this Part of the Earth, all the *Stars* riſe and ſet, and their Continuance above the Horizon, is equal to their Stay below it, *viz.* 12 Hours.

If from this Poſition we gradually move the Globe according to the ſeveral Alterations of Latitudes, which we will ſuppoſe to be Northerly; the Lengths of the *Diurnal Arches* will continually increaſe, until we come to a Parallel of Declination, as far diſtant from the Equinoctial, as the Place itſelf is from the Pole. This Parallel will juſt touch the Horizon, and all the Heavenly Bodies that are betwixt it and the Pole never deſcend below the Horizon. In the mean time, while we are moving the Globe, the Lengths of the Diurnal Arches of the Southern Parallels of Declination, continually diminiſh in the ſame Proportion that the Northern ones increaſed; until we come to that Parallel of Declination which is ſo far diſtant from the Equinoctial Southerly, as the Place itſelf is from the North Pole. The upper Part of this *Parallel* juſt touches the Horizon, and all the Stars that are betwixt it and the South Pole never appear above the Horizon. All the Nocturnal Arches of the Southern Parallels of Declination, are exactly in the ſame Length with the Diurnal Arches of the correſpondent Parallels of North Declination.

2. Let us take a View of the Globe, when it is rectified for the Latitude of *London*, or 51 ½ Degrees North. When the Sun is in the Tropic of ♋, the Day is about 16 ½ Hours; as he recedes from this Tropic, the Days proportionably ſhorten, until he arrives into ♑, and then the Days are at the ſhorteſt, being now of the ſame Length with the Night when the Sun was in ♋, *viz.* 7 ½ Hours. The lower Part of that Parallel of Declination, which is 38 ½ Degrees from the Equinoctial Northerly, juſt touches the Horizon; and all the Stars that are betwixt this Parallel and the North Pole, never ſet to us at *London*. In like Manner the upper Part of the Southern Parallel of 38½ Degrees juſt touches the Horizon, and all the Stars that lie betwixt this Parallel and the South Pole are never viſible in this Latitude.

Again, let us rectify the Globe for the Latitude of the *Arctic Circle*, we ſhall then find, that when the Sun is in ♋, he touches the Horizon on that Day without ſetting, being 24 Hours compleat above the Horizon; and when he is in *Capricorn*, he once appears in the Horizon, but does not riſe in the Space of 24 Hours: When he is in any other Point of the Ecliptic, the Days are longer or ſhorter according to his Diſtance from the Tropics. All the Stars that lie between the Tropic of *Cancer*, and the North Pole, never ſet in this Latitude; and thoſe that are between the Tropic of *Capricorn*, and the South Pole, are always hid below the Horizon.

If we elevate the Globe ſtill higher, the Circle of *perpetual Apparition* will be nearer the Equator, as will that of *perpetual Occultation* on the other Side. For Example, Let us rectify the Globe for the Latitude of 80 Degrees North; when the Sun's Declination is 10 Degrees North, he begins to turn above the Horizon without ſetting, and all the while he is making his Progreſs from this Point to the Tropic of ♋, and back again, he never ſets. After the ſame Manner, when his Declination is 10 Degrees South, he is juſt ſeen at Noon in the Horizon; and all the while he is going Southward, and back again, he diſappears, being hid juſt ſo long as before, at the oppoſite Time of the Year he appeared viſible.

Let us now bring the North Pole into the Zenith, then will the Equinoctial coincide with the Horizon; and conſequently all the Northern Parallels are above the Horizon, and the Southern ones below it. Here is but one Day and one Night throughout the Year, it being Day all the while the Sun is to the Northward of the Equinoctial, and Night for the other half Year. All the Stars that have North Declination, always appear above the Horizon, and at the ſame height; and all thoſe that are on the other Side, are never ſeen.

What has been here ſaid of rectifying the Globe to North Latitude, holds for the ſame Latitude South; only that before the longeſt Days were, when the Sun was in ♋, the ſame happening now when the Sun is in ♑; and ſo of the reſt of the Parallels, the Seaſons being directly oppoſite to thoſe who live in different Hemiſpheres.

I ſhall again explain ſome Things delivered above in general Terms, by particular Problems.

But from what has been already ſaid, we may firſt make the following Obſervations:

1. *All Places of the Earth do equally enjoy the Benefit of the Sun, in reſpect of Time, and are equally deprived of it, the Days at one Time of the Year being exactly equal to the Nights at the oppoſite Seaſon.*

2. *In all Places of the Earth, ſave exactly under the Poles, the Days and Nights are of equal Length* (viz. 12 *Hours each*) *when the Sun is in the Equinoctial.*

3. *Thoſe who live under the Equinoctial have the Days and Nights of equal Lengths at all Times of the Year.*

4. *In all Places between the Equinoctial and the Poles, the Days and Nights are never equal, but when the Sun is in the Equinoctial Points ♈ and ♎.*

5. *The nearer any Place is to the Equator, the leſs is the Difference between the Length of the Artificial Days and Nights in the ſaid Place; and the more remote the greater.*

6. *To all the Inhabitants lying under the ſame Parallel of Latitude, the Days and Nights are of equal Lengths, and that at all Times of the Year.*

7. *The Sun is Vertical twice a Year to all Places between the Tropics; to thoſe under the Tropics, once a Year, but never any where elſe.*

8. *In all Places between the Polar Circles, and the Poles, the Sun appears ſome Number of Days without ſetting; and at the oppoſite Time of the Year he is for the ſame Length of Time without riſing; and the nearer unto, or further remote from the Pole, thoſe Places are, the longer or ſhorter is the Sun's*

Sun's continued Preſence in, or Abſence from the ſame.

9. *In all Places lying exactly under the Polar Circles, the Sun, when he is in the neareſt Tropic, appears* 24 *Hours without ſetting; and when he is in the contrary Tropic, he is for the ſame Length of Time without riſing; but at all other Times of the Year he riſes and ſets there, as in other Places.*

10. *In all Places lying in the* $\left\{\begin{matrix}\textit{Northern}\\ \textit{Southern}\end{matrix}\right\}$ *Hemiſphere, the Longeſt Day and Shorteſt Night, is when the Sun is in the* $\left\{\begin{matrix}\textit{Northern}\\ \textit{Southern}\end{matrix}\right\}$ *Tropic; and the contrary.*

PROB. XVIII. *The Latitude of any Place, not exceeding* 66 ½ *Degrees, and the Day of the Month being given; to find the Time of Sun-riſing and ſetting, and the Length of the Day and Night.*

Having rectified the Globe according to the Latitude, bring the Sun's Place to the Meridian, and put the Hour-Index to 12 at Noon; then bring the Sun's Place to the Eaſtern Part of the Horizon, and the Index will ſhew the Time when the Sun riſes. Again, turn the Globe until the Sun's Place be brought to the Weſtern Side of the Horizon, and the Index will ſhew the Time of Sun-ſetting.

The Hour of Sun-ſetting doubled, gives the Length of the Day; and the Hour of Sun-riſing doubled, gives the Length of the Night.

Let it be required to find when the Sun riſes and ſets at *London* on the 20th of *April.* Rectify the Globe for the Latitude of *London*, and having found the Sun's Place correſponding to *May* the 1ſt, *viz.* ♉ $10\frac{3}{4}$ Degree, bring ♉ $10\frac{3}{4}$ Degrees to the Meridian, and ſet the Index at 12 at Noon; then turn the Globe about till ♉ $10\frac{3}{3}$ Degrees be brought to the Eaſtern Part of the Horizon, and you'll find the Index point $4\frac{3}{4}$ Hours; this being doubled, gives the Length of the Night $9\frac{1}{2}$ Hours. Again, bring the Sun's Place to the Weſtern Part of the Horizon, and the Index will point $7\frac{1}{4}$ Hours, which is the Time of Sun-ſetting; this being doubled, gives the Length of the Day $14\frac{1}{2}$ Hours.

PROB. XIX. *To find the Length of the Longeſt and ſhorteſt Day and Night in any given Place, not exceeding* $66\frac{1}{2}$ *Degrees of Latitude.*

Note, The Longeſt Day at all Places on the $\left\{\begin{matrix}\text{North}\\ \text{South}\end{matrix}\right\}$ Side of the Equator, is when the Sun is in the firſt Point of $\left\{\begin{matrix}\textit{Cancer,}\\ \textit{Capricorn:}\end{matrix}\right\}$

Wherefore having rectified the Globe for the Latitude, find the Time of Sun-riſing and ſetting, and thence the Length of the Day and Night, as in the laſt Problem, according to the Place of the Sun: Or having rectified the Globe for the Latitude, bring the Solſtitial Point of that Hemiſphere to the Eaſt Part of the Horizon, and ſet the Index 12 at Noon; then turning the Globe about till the ſaid Solſtitial Point touches the Weſtern Side of the Horizon, the Number of Hours from Noon to the Place where the Index points (being counted according to the Motion of the Index) is the Length of the Longeſt Day; the Complement whereof to 24 Hours, is the Length of the Shorteſt Night, and the Reverſe gives the ſhorteſt Day and the Longeſt Night.

	Longeſt Day.		*Short N.*
	Deg.	*Hours.*	*Hours.*
Thus in Lat.	45	15 ½	8 ½
	51 ½	16 ½	7 ½
	60	17 ½	5 ½

If from the Length of the Longeſt Day you ſubtract 12 Hours, the Number of half Hours remaining will be the *Climate*: Thus that Place where the longeſt Day is 16 ½ Hours, lies in the 9th *Climate*. And by the Reverſe, having the *Climate*, you have thereby the Length of the Longeſt Day.

PROB. XX. *To find in what Latitude the Longeſt Day is, of any given Length leſs than* 24 *Hours.*

Bring the Solſtitial Point to the Meridian, and ſet the Index to 12 at Noon; then turn the Globe Weſtward till the Index points at half the Number of Hours given; which being done, keep the Globe from turning round its Axis, and ſlide the Meridian up or down in the Notches, till the Solſtitial Point comes to the Horizon, then that Elevation of the Pole will be the Latitude.

If the Hours given be 16, the Latitude is 49 Degrees; if 20 Hours, the Latitude is 63 $\frac{1}{4}$ Degrees.

PROB. XXI. *A Place being given in one of the* Frigid Zones *(ſuppoſe the* Northern) *to find what Number of Days (of* 24 *Hours each) the Sun doth conſtantly ſhine upon the ſame, how long he is abſent, and alſo the firſt and laſt Day of his Appearance.*

Having rectified the Globe according to the Latitude, turn it about until ſome Point in the firſt Quadrant of the Ecliptic (becauſe the Latitude is North) interſects the Meridian in the North Point of the Horizon; and right againſt that Point of the

Ecliptic on the Horizon, ſtands the Day of the Month when the Longeſt Day begins.

And if the Globe be turned about till ſome Point in the ſecond Quadrant of the Ecliptic cuts the Meridian in the ſame Point of the Horizon, it will ſhew the Sun's Place when the Longeſt Day ends, whence the Day of the Month may be found as before: Then the Number of Natural Days contained between the Times the Longeſt Day begins and ends, is the Length of the Longeſt Day required.

Again, turn the Globe about, until ſome Point in the third Quadrant of the Ecliptic cuts the Meridian in the South Part of the Horizon; that Point of the Ecliptic will give the Time when the Longeſt Night begins. Laſtly, turn the Globe about until ſome Point in the fourth Quadrant of the Ecliptic cuts the Meridian in the South Point of the Horizon; and that Point of the Ecliptic will be the Place of the Sun, when the Longeſt Night ends.

Or, the Time when the Longeſt Day or Night begins, being known, their End may be found by counting the Number of Days from that Time to the ſucceeding Solſtice; then counting the ſame Number of Days from the Solſtitial Day, will give the Time when it ends.

PROB. XXII. *To find in what Latitude the Longeſt Day is of any given Length leſs than* 182 *Natural Days.*

Find a Point in the Ecliptic half ſo many Degrees diſtant from the Solſtitial Point, as there are Days given, and bring that Point to the Meridian; then keep the Globe from turning round its Axis, and move the Meridian up or down until the aforeſaid Point of the Ecliptic comes to the Horizon; that Elevation of the Pole will be the Latitude required.

If the Days given were 78, the Latitude is 71 ½ Degrees.

This method is not accurate, becauſe the Degrees in the Ecliptic do not correſpond to Natural Days; and alſo becauſe the Sun does not always move in the Ecliptic at the ſame Rate; however, ſuch Problems as theſe may ſerve for Amuſements.

PROB. XXIII. *The Day of the Month being given, to find when the Morning and Evening* Twilight *begins and ends, in any Place upon the Globe.*

In the foregoing Problem, by the Length of the Day, we mean the Time from Sun-riſing to Sun-ſet; and the Night we reckoned from Sun-ſet, till he roſe next Morning; But it is found by Experience, that *Total Darkneſs*

Darkneſs does not commence in the Evening, till the Sun has got 18 Degrees below the Horizon; and when he comes within the ſame Diſtance of the Horizon next Morning, we have the firſt *Dawn of Day.* This faint Light which we have in the Morning and Evening, before and after the Sun's riſing and ſetting, is what we call the *Twilight.*

* Having rectified the Globe for the Latitude, the Zenith, and the Sun's Place, turn the Globe and the Quadrant of Altitude until the Sun's Place cuts 18 Degrees below the Horizon (if the Quadrant reaches ſo far) then the Index upon the Hour-Circle will ſhew the Beginning or Ending of Twilight after the ſame Manner as before we found the Time of Sun-riſing and ſetting, in *Prob.* 18. But by reaſon of the Thickneſs of the Wooden Horizon, we can't conveniently ſee, or compute when the Sun's Place is brought to the Point aforeſaid. Wherefore the Globe being rectified as above directed, turn the Globe and alſo the Quadrant of Altitude Weſtward, until that Point in the Ecliptic, which is oppoſite to the Sun's Place, cuts the Quadrant in the 18th Degree above the Horizon; then the Hour-Index will ſhew the Time when Day breaks in the Morning. And if you turn the Globe and the Quadrant of Altitude, until the Point oppoſite to the Sun's

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Sun's Place cuts the Quadrant in the 18th Degree in the Eaſtern Hemiſphere, the Hour-Hand will ſhew when Twilight ends in the Evening. Or, having found the Time from Midnight when the Morning Twilight begins, if you reckon ſo many Hours before Midnight, it will give the Time when the Evening Twilight ends. Having found the Time when Twilight begins in the Morning, find the Time of Sun-riſing, by *Prob.* 18. and the Difference will be the Duration of Twilight.

Thus at *London* on the 12th of *May*, Twilight begins at three Quarters paſt One o'Clock; the Sun riſes at about half an hour paſt Four: Whence the Duration of Twilight now is 2¾ Hours, both in the Morning and Evening. On the twelfth of *November*, the Twilight begins at Half an Hour paſt Six, being ſomewhat above an Hour before Sun-riſing.

PROB. XXIV. *To find the Time when total Darkneſs ceaſes, or when the Twilight continues from Sun-ſetting to Sun-riſing, in any given Place.*

Let the Place be in the Northern Hemiſphere; then if the Complement of the Latitude be greater than (the Depreſſion) 18 Degrees, ſubtract 18 Degrees from it, and the Remainder will be the Sun's Declination North when total Darkneſs ceaſes. But if the Complement of the Latitude is leſs than 18 Degrees, their Difference will be the Sun's Declination South, when the Twilight begins to continue all Night. If the Latitude is South, the only Difference will be, that the Sun's Declination will be on the contrary Side.

Thus at *London*, when the Sun's Declination North is greater than 20 $\frac{1}{2}$ Degrees, there is no total Darkneſs, but conſtant Twilight, which happens from the 26th of *May* to the 18th of *July*, being near two Months. Under the North Pole the Twilight ceaſes, when the Sun's Declination is greater than 18 Degrees South, which is from the 13th of *November*, till the 29th of *January*: So that notwithſtanding the Sun is abſent in this Part of the World for Half a Year together, yet total Darkneſs does not continue above 11 Weeks; and beſides, the *Moon* is above the Horizon for a whole Fortnight of every Month throughout the Year.

PROB. XXV. *The Day of the Month being given; to find thoſe Places of the Frigid Zones, where the Sun begins to ſhine conſtantly without ſetting; and alſo thoſe Places where he begins to be totally abſent.*

Bring the Sun's Place to the Meridian, and mark the Number of Degrees contain'd betwixt that Point and the Equator; then count the ſame Number of Degrees from the neareſt Pole (*viz.* the North Pole, if the Sun's Declination is Northerly, otherwiſe the South Pole) towards the Equator, and note that Point upon the Meridian; then turn the Globe about, and all the Places which paſs under the ſaid Point, are thoſe where the Sun begins to ſhine conſtantly, without ſetting on the given Day. If you lay the ſame Diſtance from the oppoſite Pole towards the Equator, and turn the Globe about, all the Places which paſs under that Point, will be thoſe where the longeſt Night begins.

The Latitude of the Place being given, to find the Hour of the Day when the Sun ſhines.

If it be in the Summer, elevate the Pole according to the Latitude, and ſet the Meridian due North and South; then the Shadow of the Axis will cut the Hour on the Dial-Plate: For the Globe being rectified in this Manner, the Hour Circle is a true *Equinoctial Dial*; the Axis of the Globe being the *Gnomon*. This holds true in *Theory*, but it might not be very accurate in Practice, becauſe of the Difficulty in placing the Horizon of the Globe truly horizontal, and its Meridian due North and South.

If it be in the Winter Half Year, elevate the South Pole according to the Latitude North, and let the North Part of the Horizon be in the South Part of the Meridian; then the Shade of the Axis will ſhew the Hour of the Day as before: But this cannot be ſo conveniently performed, tho' the Reaſon is the ſame as in the former Caſe.

To find the Sun's Altitude, when it ſhines, by the Globe.

Having ſet the Frame of the Globe truly horizontal or level, turn the North Pole towards the Sun, and move the Meridian up or down in the Notches, till the Axis caſts no Shadow; then the Arch of the Meridian, contain'd betwixt the Pole and the Horizon, is the Sun's Altitude.

Note, The beſt Way to find the Sun's Altitude, is by a little Quadrant graduated into Degrees, and having Sights and a Plummet to it: Thus, hold the Quadrant in your Hand, ſo as the Rays of the Sun may paſs through both the Sights, the Plummet then hanging freely by the Side of the Inſtrument, will cut in the Limb the Altitude required. These Quadrants are to be had at the Inſtrument-Makers, with Lines drawn upon them, for finding the Hour of the Day and the Azimuth, with ſeveral other pretty Concluſions, very entertaining for Beginners.

The Latitude, and the Day of the Month being given, to find the Hour of the Day when the Sun ſhines.

Having placed the Wooden Frame upon a Level, and the Meridian due North and South, rectify the Globe for the Latitude, and fix a Needle perpendicularly over the Sun's Place: The Sun's Place being brought to the Meridian, ſet the Hour-Index at 12 at Noon, then turn the Globe about until the Needle points exactly to the Sun, and caſts no Shadow, and then the Index will ſhew the Hour of the Day.

Prob. XXVI. *The Latitude, the Sun's Place, and his Altitude, being given; to find the Hour of the Day, and the Sun's Azimuth from the Meridian.*

Having rectified the Globe for the Latitude, the Zenith, and the Sun's Place, turn the Globe and the Quadrant of Altitude, ſo that the Sun's Place may cut the given Degree of Altitude: then the Index will ſhew the Hour, and the Quadrant will cut the Azimuth in the Horizon. Thus, if at *London*, on the 21ſt of *Auguſt*, the Sun's Altitude be 36 Degrees in the Forenoon, the Hour of the Day will be IX, and the Sun's Azimuth about 58 Degrees from the South Part of the Meridian.

The Sun's Azimuth being given, to place the Meridian of the Globe due North and South, or to find a Meridian Line when the Sun ſhines.

Let the Sun's Azimuth be 30 Degrees South-Eaſterly, ſet the Horizon of the Globe upon a Level, and bring the North Pole into the Zenith; then turn the Horizon about until the Shade of the Axis cuts as many Hours as is equivalent to the Azimuth (allowing 15 Degrees to an Hour) in the North-Weſt Part of the Hour-Circle, *viz.* X at Night, which being done, the Meridian of the Globe ſtands in the true Meridian of the Place. The Globe ſtanding in this Poſition, if you hang two Plummets at the North and South Points of the Wooden Horizon, and draw a Line betwixt them, you'll have a Meridian Line; which if it be on a fixed Plane (as a Floor or Window) it will be a Guide for placing the Globe due North and South at any other Time.

PROB. XXVII. *The Latitude, Hour of the Day, and the Sun's Place being given, to find the Sun's Altitude and Azimuth.*

Rectify the Globe for the Latitude, the Zenith, and the Sun's Place, then the Number of Degrees contained betwixt the Sun's Place and the Vertex, is the Sun's Meridional Zenith Diſtance; the Complement of which, to 90 Degrees, is the Sun's Meridian Altitude. If you turn the Globe about until the Index points to any other given Hour, then bringing the Quadrant of Altitude to cut the Sun's Place, you'll have the Sun's Altitude at that Hour; and where the Quadrant cuts the Horizon, is the Sun's Azimuth at the ſame Time. Thus *May* the 31ſt at *London*, the Sun's Meridian Altitude will be 61 $\frac{1}{2}$ Degrees; and at 10 o'Clock in the Morning, the Sun's Altitude will be 52 Degrees, and his Azimuth about 50 Degrees from the South Part of the Meridian.

PROB. XXVIII. *The Latitude of the Place, and the Day of the Month being given; to find the Depreſſion of the Sun below the Horizon, and the Azimuth at any Hour of the Night.*

Having rectified the Globe for the Latitude, the Zenith and the Sun's Place, take a Point in the Ecliptic, exactly oppoſite to the Sun's Place, and find the Sun's Altitude and Azimuth, as by the laſt Problem, and theſe will be the Depreſſion and the Altitude required. Thus, if the Time given be the 1ſt of *December*, at 10 o'Clock at Night, the Depreſſion and Azimuth will be the ſame as was found in the laſt Problem.

PROB. XXIX. *The Latitude, the Sun's Place, and his Azimuth being given; to find his Altitude, and the Hour.*

Rectify the Globe for the Latitude, the Zenith, and the Sun's Place, then put the Quadrant of Altitude to the Sun's Azimuth in the Horizon, and turn the Globe till the Sun's Place meet the Edge of the Quadrant, then the ſaid Edge will ſhew the Altitude, and the Index point to the Hour. Thus, *May* the 21ſt at *London*, when the Sun is due Eaſt, his Altitude will be about 24 Degrees, and the Hour about VII in the Morning;

and when his Azimuth is 60 Degrees South-Weſterly, the Altitude will be about 44 ½ Degrees, and the Hour about 2 ¾ in the Afternoon.

Thus, the Latitude and the Day being known, and having beſides either the Altitude, the Azimuth, or the Hour; the other two may be eaſily found.

PROB. XXX. *The Latitude, the Sun's Altitude, and his Azimuth being given; to find his Place in the Ecliptic and the Hour.*

Rectify the Globe for the Latitude and Zenith, and ſet the Edge of the Quadrant to the given Azimuth; then turning the Globe about, that Point of the Ecliptic which cuts the Altitude will be the Sun's Place. Keep the Quadrant of the Altitude in the ſame Poſition, and having brought the Sun's Place to the Meridian, and the Hour Index to 12 at Noon, turn the Globe about till the Sun's Place cuts the Quadrant of Altitude, and then the Index will point the Hour of the Day.

PROB. XXXI. *The Declination and Meridian Altitude of the Sun, or of any Star being given; to find the Latitude of the Place.*

Mark the Point of Declination upon the Meridian, according as it is either North or

South from the Equator; then ſlide the Meridian up or down in the Notches, till the Point of Declination be ſo far diſtant from the Horizon, as is the given Meridian Altitude; that Elevation of the Pole will be the Latitude.

Thus, if the Sun's, or any Star's Meridian Altitude be 50 Degrees, and its Declination $11\frac{1}{2}$ Degrees North, the Latitude will be $51\frac{1}{2}$ Degrees North.

PROB. XXXII. *The Day and Hour of a Lunar Eclipſe being known; to find all thoſe Places upon the Globe in which the ſame will be viſible.*

* Find where the Sun is vertical at the given Hour, and bring that Point to the Zenith; then the Eclipſe will be viſible in all thoſe Places that are under the Horizon: Or, if you bring the Antipodes to the Place where the Sun is vertical, into the Zenith, you will have the Places where the Eclipſe will be viſible above the Horizon. **Prob.* XIII.

Note, Becauſe *Lunar* Eclipſes continue ſometimes for a long while together, they may be ſeen in more Places than one Hemiſphere of the Earth; for by the Earth's Motion round its Axis, during the Time of the Eclipſe, the Moon will riſe in ſeveral Places after the Eclipſe began.

Note, When an Eclipſe of the Sun is central, if you bring the Place where the

Sun is vertical at that Time, into the Zenith, ſome Part of the Eclipſe will be viſible in moſt Places within the upper Hemiſphere; but by Reaſon of the ſhort Duration of Solar Eclipſes, and the Latitude which the Moon commonly has at that Time, (tho' but ſmall) there is no Certainty in determining the Places where thoſe Eclipſes will be viſible by the Globe; but Recourſe muſt be had to Calculations.

PROB. XXXIII. *The Day of the Month, and Hour of the Day, according to our Way of reckoning in* England, *being given to find thereby the* Babylonic, Italic, *and the* Jewiſh *or Judaical Hour.*

1. To find the *Babylonic Hour* (which is the Number of Hours from Sun-riſing.) Having found the Time of Sun-riſing in the given Place, the Difference betwixt this and the Hour given is the *Babylonic* Hour.

2. To find the *Italic Hour* (which is the Number of Hours from Sun-ſetting.) Subtract the Hour of Sun-ſetting from the given Hour, and the Remainder will be the *Italic Hour* required.

3. To find the *Jewiſh Hour* (which is $\frac{1}{12}$ Part of an *Artificial* Day.) Find how many Hours the Day conſiſts of; then ſay, as the Number of Hours the Day conſiſts of is to 12 Hours, ſo is the Hour ſince Sun-riſing to the *Judaical* Hour required.

Thus, if the Sun riſes at 4 o'Clock (conſequently ſets at 8) and the Hour given be 5 in the Evening, the *Babylonic* Hour will be the 13th, the *Italic* the 21ſt, and the *Jewiſh* Hour will be Nine, and Three Quarters.

The Converſe being given, the Hour of the Day, according to our Way of reckoning in *England*, may be eaſily found.

The following Problems are peculiar to the *Celeſtial* Globe.

PROB. XXXIV. *To find the Right Aſcenſion and Declination of the Sun or any Fixed Star.*

Bring the Sun's Place in the Ecliptic to the Meridian; then that Degree of the Equator, which is cut by the Meridian, will be the *Sun's Right Aſcenſion*; and that Degree of the Meridian, which is exactly over the Sun's Place, is the *Sun's Declination.*

After the ſame Manner, bring the Place of any Fixed Star to the Meridian, and you'll find its Right Aſcenſion in the Equinoctial, and Declination of the Meridian.

Thus, the Right Aſcenſion and Declination is found, after the ſame Manner as the Longitude and Latitude of a Place upon the *Terreſtrial* Globe.

Note, The Right Aſcenſion and Declination of the Sun vary every Day; but the

Right Aſcenſion, *&c.* of the Fixed Stars is the ſame throughout the Year †.

Thus on	The Sun's Right Aſcenſion. *Deg.*	Declin. *Deg.*
January 31 ——	314	—$17\frac{1}{3}$ S.
April 5 ——	$14\frac{1}{4}$	— 6 N.
July 21 ——	$120\frac{1}{4}$	—$20\frac{1}{2}$ N.
November 26 ——	242	—21 S.

	R. Aſc. *Deg.*	Decl. *Deg.*
Aldebaran —— —	65	16 N.
Spica Virginis ——	$197\frac{3}{4}$	$9\frac{3}{4}$ S.
Capella —— ——	74	$45\frac{2}{3}$ N.
Syrius, or the Dog-Star ——	$98\frac{1}{4}$	$16\frac{1}{3}$ S.

Note, The Declination of the Sun may be found after the ſame Manner, by the *Terreſtrial* Globe, and alſo his Right Aſcenſion, when the Equinoctial is numbered into 360 Degrees, commencing at the Equinoctial Point ♈: But as the Equinoctial is not always numbered ſo, and this being properly a Problem in *Aſtronomy*, we chuſe rather to place it here.

By the Converſe of this Problem, having the Right Aſcenſion and Declination of any

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† The inſenſible Change in the Longitude, Right-Aſcenſion, and Declination of the Fixed Stars, made by their ſlow Motion, parallel to the Ecliptic (being but 1 Degree in 72 Years) is not worth Notice in this Place.

Point given, that Point itſelf may be eaſily found upon the Globe.

PROB. XXXV. *To find the Longitude and Latitude of a given Star.*

Having brought the Solſtitial Colure to the Meridian, fix the Quadrant of Altitude over the proper Pole of the Ecliptic, whether it be North or South; then turn the Quadrant over the given Star, and the Arch contain'd betwixt the Star and the Ecliptic will be the Latitude, and the Degree cut on the Ecliptic will be the Star's Longitude.

Thus the Latitude of *Arcturus* will be found to be 31 Degrees North, and the Longitude 200 Degrees from ♈, or 20 Degrees from ♎: The Latitude of *Fomalhaut* in the Southern Fiſh, 21 Degrees South, and Longitude 299 $\frac{1}{2}$ Degrees, or ♑ 29 $\frac{1}{2}$ Degrees. By the Converſe of this Method, having the Latitude and Longitude of a Star given, it will be eaſy to find the Star upon the Globe.

The Diſtance betwixt two Stars, or the Number of Degrees contained betwixt them, may be found by laying the Quadrant of Altitude over each of them, and counting the Number of Degrees intercepted; after the ſame Manner as we found the Diſtance betwixt two Places on the *Terreſtrial* Globe, in *Prob.* VII.

PROB. XXXVI. *The Latitude of the Place, the Day of the Month, and the Hour being given; to find what Stars are then riſing or ſetting, what Stars are culminating or on the Meridian, and the Altitude and Azimuth of any Star above the Horizon; and alſo how to diſtinguiſh the Stars in the Heavens one from the other, and to know them by their proper Names.*

Having rectified the Globe for the Latitude, the Zenith, and the Sun's Place, turn the Globe about until the Index points to the given Hour, the Globe being kept in this Poſition.

All thoſe Stars that are in the $\left\{\begin{array}{l}\text{Eaſtern}\\ \text{Weſtern}\end{array}\right\}$ Side of the Horizon, are then $\left\{\begin{array}{l}\text{Riſing.}\\ \text{Setting.}\end{array}\right\}$

All thoſe Stars that are under the Meridian are then culminating. And if the Quadrant of Altitude be laid over the Center of any particular Star, it will ſhew that Star's Altitude at that Time; and where it cuts the Horizon, will be the Star's Azimuth from the North or South Part of the Meridian.

The Globe being kept in the ſame Elevation, and from turning round its Axis, move the wooden Frame about until the North and South Points of the Horizon lie exactly in the Meridian; then right Lines imagined to paſs from the Center thro' each Star upon the Surface of the Globe, will point out the real Stars in the Heavens, which thoſe on the Globe are made to repreſent. And if you are by the Side of ſome Wall, whoſe Bearing you know, lay the Quadrant of Altitude to that Bearing in the Horizon, and it will cut all thoſe Stars, which at that very Time are to be ſeen in the ſame Direction, or cloſe by the Side of the ſaid Wall. Thus knowing ſome of the remarkable Stars in any Part of the Heavens, the Neighbouring Stars may be diſtinguiſhed by obſerving their Situations with reſpect to thoſe that are already known, and comparing them with the Stars drawn upon the Globe.

Thus, if your turn your Face towards the North, you will find the North Pole of the Globe points to the *Pole-Star*; then you may obſerve two Stars ſomewhat leſs bright than the Pole-Star, almoſt in a right Line with it, and four more which form a Sort of a *Quadrangle*; theſe ſeven Stars make the Conſtellation called the *Little-Bear*; the Pole Star being in the Tip of the Tail. In this Neighbourhood you'll obſerve ſeven bright Stars, which are commonly called *Charles's Wane*; theſe are the bright Stars in the *Great Bear*, and do form much ſuch another Figure with thoſe before-mentioned in the *Little Bear:* The two foremoſt of the Square lie almoſt in a right Line with the Pole Star, and are called the *Pointers* ; ſo that knowing the Pointers, you may eaſily find the Pole-Star. Thus the reſt of the Stars in this Conſtellation, and all the Stars in the neighbouring Conſtellations, may be eaſily found, by obſerving how the unknown Stars lie either in *Quadrangles*, *Triangles*, or ſtrait Lines, from thoſe that are already known upon the Globe.

After the ſame Manner the Globe being rectified, you may diſtinguiſh thoſe Stars that are to the Southward of you, and be ſoon acquainted with all the Stars that are viſible in our Hemiſphere.

SCHOLIUM.

The Globe being rectified to the Latitude of any Place, if you turn it round its Axis, all thoſe Stars that do not go below the Horizon during a whole Revolution of the Globe, never ſet in that Place; and thoſe that do not come above the Horizon never riſe.

Prob. XXXVII. *The Latitude of the Place being given; to find the Amplitude, Oblique Aſcenſion and Deſcenſion, Aſcenſional Difference, Semi-Diurnal Arch, and the Time of Continuance above the Ho-*

Horizon, of any given Point in the Heavens.

Having rectified the Globe for the Latitude, and brought the given Point to the Meridian, ſet the Index to the Hour of 12; then turn the Globe until the given Point be brought to the Eaſtern Side of the Horizon, and that Degree of the Equinoctial which is cut by the Horizon at that Time, will be the *Oblique Aſcenſion*; and where the given Point cuts the Horizon, is the *Amplitude Ortive:* If the Globe be turned about until the given Point be brought to the Weſtern Side of the Horizon, it will there ſhew the *Amplitude Occaſive*; and where the Horizon cuts the Equinoctial at that Time is the *Oblique Deſcenſion.*

The Time between the Index at either of theſe two Poſitions, and the Hour of 6; or Half the Difference between the Oblique Aſcenſion and Deſcenſion is the *Aſcenſional Difference.*

If the Place be in North Latitude, and the Declination of the given Point be $\left\{\begin{matrix}\text{North}\\ \text{South}\end{matrix}\right\}$ the Aſcenſional Difference reduced into Time, and $\left\{\begin{matrix}\text{added to}\\ \text{ſubtracted from}\end{matrix}\right\}$ 6 o'Clock, gives the *Semi-Diurnal Arch*; the Complement whereof to a Semicircle, is the *Semi-Nocturnal Arch.* If the Place be in

South Latitude, then the contrary is to be obſerved with reſpect to the Declination.

The Semi- $\left\{\begin{array}{c}\text{Diurnal}\\ \text{Nocturnal}\end{array}\right\}$ Arch being doubled, gives the Time of Continuance $\left\{\begin{array}{l}\text{above}\\ \text{below}\end{array}\right\}$ the Horizon. Or the Time of Continuance above the Horizon, may be found by counting the Number of Hours contained in the upper Part of the Horary Circle, betwixt the Places where the Index prointed when the given Point was in the Eaſtern and Weſtern Parts of the Horizon. If the given Point was the Sun's Place, the Index pointed the Time of his Riſing and Setting, when the ſaid Place was in the Eaſtern and Weſtern Parts of the Horizon, as in *Prob.* 18. Or the Time of Sun-riſing may be found by adding or ſubtracting his Aſcenſional Difference, to or from the Hour of Six, according as the Latitude and Declination are either contrary or the ſame Way.

Thus, at *London*, on the 31ſt of *May*, the *Sun's*

Amplitude is 24 Degrees Northerly.
Oblique Aſcenſion, 20.
Oblique Deſcenſion, 58.
Aſcenſional Difference, 19.
Semidiurnal Arch, 109.

His Continuance above the Horizon, $14\frac{1}{2}$ Hours.

Sun riſes at three Quarters paſt Four.
Sun ſets at a Quarter paſt Seven.

Theſe Things for the Sun vary every Day; but for a fixed Star the Day of the Month need not be given, for they are the ſame all the Year round.

In the Latitude of 51 ½ North, *Syrius*'s *Amplitude* is about 28 Degrees Southerly.
Oblique Aſcenſion, 121.
Oblique Deſcenſion, 75.
Aſcenſional Difference, 23.
Semidiurnal Arch, 67.
Continuance above the Horizon, 9 Hours.

PROB. XXXVIII. *The Latitude and the Day of the Month being given; to find the Hour when any known Star will be on the Meridian, and alſo the Time of its Riſing and Setting.*

Having rectified the Globe for the Latitude of the Sun's Place, bring the given Star to the Meridian, and alſo to the Eaſt or Weſt Side of the Horizon, and the Index will ſhew accordingly when the Star *culminates*, or the Time of the *Riſing* or *Setting*.

Thus, at *London*, on the 21ſt of *January*, *Syrius* will be upon the Meridian at a Quarter paſt Ten in the Evening, riſes at 5 ¼ Hours, and ſets at three Quarters paſt Two in the Morning.

By the Converſe of this Problem, knowing the Time when any Star is upon the Meridian, you may eaſily find the Sun's Place. Thus, bring the given Star to the Meridian, and ſet the Index to the given Hour; then turn the Globe till the Index points to 12 at Noon, and the Meridian will cut the Sun's Place in the Ecliptic. Thus when *Syrius* comes to the Meridian at 10 ½ Hours after Noon, the Sun's Place will be ♒ 1 ¼ Deg.

Prob. XXXIX. *To find at what Time of the Year a given Star will be upon the Meridian, at a given Hour of the Night.*

Bring the Star to the Meridian, and ſet the Index to the given Hour, then turn the Globe till the Index points to 12 at Noon, and the Meridian will cut the Ecliptic in the Sun's Place; whence the Day of the Month may be eaſily found in the Calendar upon the Horizon.

Prob. XL. *The Day of the Month, and the Azimuth of any known Star being given; to find the Hour of the Night.*

Having rectified the Globe for the Latitude and the Sun's Place, if the given Star be due North or South, bring it to the Meridian, and the Index will ſhew the Hour of the Night. If the Star be in any other Direction,

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fix the Quadrant of Altitude in the Zenith, and ſet it to the Star's Azimuth in the Horizon; then turn the Globe about until the Quadrant cuts the Center of the Star, and the Index will ſhew the Hour of the Night.

The Bearing of any Point in the Heavens may be found by the following Methods.

Having a Meridian Line drawn in two Windows, that are oppoſite to one another, you may croſs it at right Angles with another Line repreſenting the Eaſt and Weſt; from the Point of Interſection deſcribe a Circle, and divide each Quadrant into 90 Degrees; then get a ſmooth Board, of about 2 Feet long, and $\frac{3}{4}$ Foot broad, (more or leſs, as you judge convenient) and on the back Part of it fix another ſmall Board croſſways, ſo that it may ſerve as a Foot to ſupport the biggeſt Board upright, when it is ſet upon a Level, or an Horizontal Plain. The Board being thus prepared, ſet the lower Edge of the ſmooth, or fore Side of it, cloſe to the Center of the Circle, then turn it about to the Meridian, or to any Azimuth Point required (keeping the Edge of it always cloſe to the Center) and caſting your Eye along the flat Side of it, you'll eaſily perceive what Stars are upon the Meridian, or any other Bearing that the Board is ſet to.

PROB. XLI. *Two known Stars having the ſame Azimuth, or the ſame Height, being given; to find the Hour of the Night.*

Rectify the Globe for the Latitude, the Zenith, and the Sun's Place.

1. When the two Stars are in the ſame Azimuth, turn the Globe, and alſo the Quadrant about, until both the Stars coincide with the Edge thereof; then will the Index ſhew the Hour of the Night; and where the Quadrant cuts the Horizon, is the common Azimuth of both Stars.

2. If the two Stars are of the ſame Altitude, move the Globe ſo that the ſame Degree on the Quadrant will cut both Stars, then the Index will ſhew the Hour.

This Problem is uſeful when the Quantity of the Azimuth of the two Stars in the firſt Caſe, or of their Altitude in the latter Caſe, is not known.

If two Stars were given, one on the Meridian, and the other in the Eaſt or Weſt Part of the Horizon; to find the Latitude.

Bring that Star which was obſerved on the Meridian, to the Meridian of the Globe, and keep the Globe from turning round its Axis; then ſlide the Meridian up or down in the Notches, till the other Star is brought to the Eaſt or Weſt Part of the Horizon, and that Elevation of the Pole will be the *Latitude* ſought.

PROB. XLII. *The Latitude, Day of the Month, and the Altitude of any known Star being given; to find the Hour of the Night.*

Rectify the Globe for the Latitude, Zenith, and Sun's Place: Turn the Globe, and the Quadrant of Altitude, backward or forward, till the Center of that Star meets the Quadrant in the Degree of Altitude given; then the Index will point the true Hour of the Night; and alſo where the Quadrant cuts the Horizon, will be the Azimuth of the Star at that Time.

If the Latitude, Sun's Altitude, and his Declination (inſtead of his Place in the Ecliptic) are given; to find the Hour of the Day, and Azimuth.

Rectify the Globe for the Latitude and Zenith, and having brought the *Equinoctial Colure* to the Meridian, ſet the Index to 12 at Noon; which being done, turn the Globe and the Quadrant, until the given Declination in the Equinoctial Colure cuts the Altitude on the Quadrant; then the Index will ſhew the *Hour* of the Day, and the Quadrant cut the *Azimuth* in the Horizon.

If the Altitude of two Stars on the ſame Azimuth, were given ; to find the Latitude of the Place.

Set the Quadrant over both Stars at the obſerved Degrees of Altitude, and keep it faſt upon the Globe with your Fingers; then ſlide the Meridian up or down in the Notches, till the Quadrant cuts the given Azimuth in the Horizon; that Elevation of the Pole will be the Latitude required.

PROB. XLIII. *Having the Latitude of the Place, to find the Degree of the Ecliptic, which riſes or ſets with a given Star ; and from thence to determine the Time of its* Coſmical *and* Achronical *Riſing and Setting.*

Having rectified the Globe for the Latitude, bring the given Star to the Eaſtern Side of the Horizon, and mark what Degree of the Ecliptic riſes with it: Look for that Degree in the Wooden Horizon, and right againſt it, in the Kalendar, you'll find the Month and Day when the Star *riſes Coſmically*. If you bring the Star to the Weſtern Side of the Horizon, that Degree of the Ecliptic which riſes at that Time, will give the Day of the Month when the ſaid Star *ſets Coſmically*. So likewiſe againſt the Degree which ſets with the Star, you'll find the Day of the Month of the *Achronical Setting*; and if you bring it to the Eaſtern Part of the Horizon, that Degree which ſets at that Time will be the Sun's Place when the Star *riſes Achronically*.

Thus, in the Latitude of *London*, *Syrius*, or the *Dog-Star*, riſes *Coſmically* the 10th of *Auguſt*, and ſets *Coſmically* the 10th of *October*. *Aldebaran*, or the *Bull's Eye*, riſes *Achronically* on the 22d of *May*, and ſets *Achronically* on the 19th of *December*.

PROB. XLIV. *Having the Latitude of the Place, to find the Time when a Star riſes and ſets* Heliacally.

Having rectified the Globe for the Latitude, bring the Star to the Eaſtern Side of the Horizon, and turn the Quadrant round to the Weſtern Side, till it cuts the Ecliptic in twelve Degrees of Altitude above the Horizon, if the Star be of the firſt Magnitude; then that Point of the Ecliptic which is cut by the Quadrant, is 12 Degrees high above the Weſtern Part of the Horizon, when the Star riſes; but at the ſame Time the oppoſite Point in the Ecliptic is 12

Degrees below the Eaſtern Part of the Horizon, which is the Depreſſion of a Star of the *firſt Magnitude*, when ſhe *riſes Heliacally*; or has got ſo far from the Sun's Beams, that ſhe may be ſeen in the Morning before Sun-riſing. Wherefore look for the ſaid Point of the Ecliptic on the Horizon, and right againſt it will be the Day of the Month when the Star *riſes Heliacally*. To find the *Heliacal Setting*, bring the Star to the Weſt Side of the Horizon, and turn the Quadrant about to the Eaſtern Side, till the 12*th* Degree of it above the Horizon, cuts the Ecliptic; then that Degree of the Ecliptic which is oppoſite to this Point, is the Sun's Place when the Star *ſets Heliacally*.

Thus you'll find that *Arcturus* riſes Heliacally the 28th of *September*, and ſets Heliacally *December* the 2*d*.

Prob. XLV. *To find the Place of any Planet upon the Globe; and ſo by that Means, to find its Place in the Heavens: Alſo to find at what Hour any Planet will riſe or ſet, or be on the Meridian at any one Day in the Year.*

You muſt firſt ſeek in an Ephemeris, (*White*'s Ephemeris will do well enough) for the Place of the Planet propoſed on that Day; then mark that Point of the Ecliptic, either with Chalk, or by ſticking on a little black Patch; and then for that Night you may perform any Problem, as before, by a Fixed Star.

Let it be required to find the Situation of *Jupiter* among the Fixed Stars in the Heavens, and alſo whenabouts it riſes and ſets, and comes to the Meridian on the 19th of *May*, 1757, N. S. at *London*.

Looking for the 19th of *May*, 1757, in *White*'s *Ephemeris*, I find that *Jupiter*'s Place at that Time is in about 12 Degrees of ♏; Latitude about 1 $\frac{1}{4}$ Degree North. Then looking for that Point upon the Celeſtial Globe, I find that ♃ is then nearly in Conjunction with the bright Star in the Southern Balance, and about 1 Degree North of it.

To find when he riſes and ſets, and comes to the Meridian: Having put a little black Patch on the Place of *Jupiter*, elevate the Globe according to the Latitude, and having brought the Sun's Place to the Meridian, ſet the Hour-Index to 12 at Noon; then turning the Mark which was made for *Jupiter*, to the Eaſtern Part of the Horizon, I find ♃ will riſe ſomewhat more than Half an Hour after Three in the Afternoon; and turning the Globe about, I find it comes to the Meridian a little before Eleven at Night; and ſets almoſt a Quarter paſt Six next Morning.

This Example being underſtood, it will be eaſy to find when either of the other two ſuperior Planets, *viz. Mars* and *Saturn*, riſe, ſet, and come to the Meridian.

I ſhall conclude this Subject about the Globes with the following Problem.

Prob. XLVI. *To find all that Space upon the Earth, where an Eclipſe of one of the Satellites of* Jupiter *will be viſible.*

Having found that Place upon the Earth, in which the Sun is Vertical, at the Time of the Eclipſe, by *Prob.* 13. elevate the Globe according to the Latitude of the ſaid Place; then bring the Place to the Meridian, and ſet the Hour Index to 12 at Noon. If *Jupiter* be in Conſequence of the Sun, draw a Line with Black-Lead, or the like, along the Eaſtern Side of the Horizon, which Line will paſs over all thoſe Places where the Sun is ſetting at that Time; then count the Difference betwixt the Right Aſcenſion of the Sun, and that of *Jupiter*, and turn the Globe Weſtward, till the Hour-Index points to this Difference; then keep the Globe from turning round its Axis, and elevate the Meridian, according to the Declination of *Jupiter*. The Globe being in this Poſition, draw a Line along the Eaſtern Side of the Horizon; then the Space between this Line, and the Line before drawn, will comprehend all thoſe Places of the Earth where *Jupiter* will be viſible, from the ſetting of the Sun, to the ſetting of *Jupiter*.

But if *Jupiter* be in Antecedence of the Sun (*i. e.* riſes before him) having brought the Place where the Sun is Vertical, to the Zenith, and put the Hour Index to 12 at Noon, draw a Line on the Weſtern Side of the Horizon; then elevate the Globe according to the Declination of *Jupiter*, and turn it about Eaſtwards, until the Index points to ſo many Hours diſtant from Noon, as is the Difference of Right Aſcenſion of the Sun and *Jupiter*. The Globe being in this Poſition, draw a Line along the Weſtern Side of the Horizon; then the Space contained between this Line, and the other laſt drawn, will comprehend all thoſe Places upon the Earth where the Eclipſe is viſible, between the riſing of the Sun and that of *Jupiter*.

The DESCRIPTION *of the Great* ORRERY, *lately made by Mr.* THOMAS WRIGHT, Mathematical Inſtrument Maker to *His* MAJESTY.

THE ORRERY is an Aſtronomical Machine, made to repreſent the Motions of the Planets. Theſe Machines are made of various Sizes, ſome having more Planets than others; but I ſhall here confine myſelf to the Deſcription of that above mentioned.

In the Introduction we gave a ſhort Account of the *Order*, *Periods*, *Diſtances*, and *Magnitudes* of the *Primary Planets*; and of the *Diſtances* and *Periodical Revolutions* of the *Secondary Planets* round their reſpective Primaries. We ſhall here explain their *Stations*, *Retrogradations*, *Eclipſes*, and *Phaſes*, &c. but firſt let us take a general View of the *Orrery*.

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View of the *Orrery*.

The Frame which contains the Wheel-Work, *&c.* that regulates the whole *Machine*, is made of fine Ebony, and is near four Feet in Diameter; the Outſide thereof is adorned with twelve Pilaſters, curiouſly wrought and gilt: Between theſe Pilaſters the twelve Signs of the *Zodiac* are neatly painted, with gilded Frames. Above the Frame is a broad Ring, ſupported with twelve Pillars: This Ring repreſents the *Plane* of the *Ecliptic*, upon which there are two Scales of Degrees, and between thoſe the Names and Characters of the 12 Signs. Near the Outſide is a Scale of Months and Days, exactly correſponding to the Sun's Place at Noon, each Day throughout the Year.

The Deſcription of the *Orrery.*

Vide *Frontiſpiece.*

Above the Ecliptic ſtand ſome of the principal Circles of the Sphere, according to their reſpective Situations in the Heavens, *viz.* N° 10, are the two *Colures*, divided into Degrees and Half-Degrees: N° 11, is one Half of the Equinoctial Circle, making an Angle with the Ecliptic of 23 ½ Degrees. The *Tropic* of *Cancer*, and the *Arctic Circle*, are each fixed parallel, and at their proper Diſtance from the Equinoctial. On the Northern Half of the Ecliptic is a Braſs Semicircle, moveable upon two Points fixed in ♈ and ♎: This Semicircle ſerves as a moveable Horizon, to be put to any Degree of Latitude upon the North Part of the Meridian. The whole Machine is alſo ſo contrived, as to be ſet to any Latitude, without in the leaſt affecting any of the inſide Motions: For this Purpoſe there are two ſtrong Hinges (N°. 13.) fixed to the Bottom Frame, upon which the Inſtrument moves, and a ſtrong Braſs Arch, having Holes at every Degree, thro' which a ſtrong Pin is to be put, according to the Elevation. This Arch and the two Hinges ſupport the whole Machine, when it is lifted up according to any Latitude; and the Arch at other Times lies conveniently under the Bottom Frame.

When the Machine is ſet to any Latitude, (which is eaſily done by two Men, each taking hold of two Handles conveniently fixed for that Purpoſe) ſet the moveable Horizon to the ſame Degree upon the Meridian, and you may form an Idea of the reſpective Altitude, or Depreſſions of the Planets, above or below the Horizon, according to their reſpective Poſitions, with Regard to the Meridian.

Within the Ecliptic, and nearly in the ſame Plane thereof, ſtands the Sun, and all the Planets, both Primary and Secondary. The Sun (N° 1.) ſtands in the Middle of the whole Syſtem upon a Wire, making an Angle with the Plane of the Ecliptic, of about 82 Degrees; which is the Inclination of the Sun's Axis, to the Axis of the Ecliptic. Next the Sun is a ſmall Ball (N° 2.)

repreſenting *Mercury* : Next to *Mercury* is *Venus* (N° 3.) repreſented by a larger Ball, (and both theſe ſtand upon Wires, ſo that the Balls themſelves may be more viſibly perceived by the Eye.) The Earth is repreſented (N° 4.) by an Ivory Ball, all having ſome of the principal Meridians and Parallels, and a little Sketch of a Map deſcribed upon it. The Wire which ſupports the Earth makes an Angle with the Plane of the Ecliptic of 66 $\frac{1}{2}$ Degrees, which is the Inclination of the Earth's Axis to that of the Ecliptic. Near the Bottom of the Earth's Axis is a Dial-Plate (N° 9.) having an Index pointing to the Hours of the Day, as the Earth turns round its Axis.

Round the Earth is a Ring, ſupported by two ſmall Pillars, which Ring repreſents the Orbit of the Moon, and the Diviſion upon it anſwers to the Moon's Latitude; the Motion of this Ring repreſents the Motion of the Moon's Orbit, according to that of the Nodes. Within this Ring is the Moon (N° 5.) having a black Cap or Caſe, which, by its Motion, repreſents the *Phaſes* of the Moon according to her Age. Without the Orbits of the Earth and Moon is *Mars* (N° 6.) The next in Order to *Mars* is *Jupiter*, and his four Moons, (N° 7) ; each of theſe Moons is ſupported by a crooked Wire fixed in a Socket, which turns about the Pillar that ſupports *Jupiter*. Theſe Satellites may be turned by the Hand to any Poſition; and yet when the Machine is put in Motion, they'll all move in their proper Times. The outermoſt of all is *Saturn*, and his five Moons (N° 8.) Theſe Moons are ſupported and contrived after the ſame Manner with thoſe of *Jupiter*. The whole Machine is put into Motion by turning a ſmall Winch, (like the Key of a Clock, N° 14); and all the inſide Work is ſo truly wrought, that it requires but a very ſmall Strength to put the Whole in Motion.

Above the Handle there is a Cylindrical Pin, which may be drawn a little out, or puſhed in at Pleaſure: When it is puſhed in, all the Planets, both Primary and Secondary, will move according to their reſpective Periods, by turning the Handle: When it is drawn out, the Motions of the Satellites of *Jupiter* and *Saturn* will be ſtopped, while all the reſt move without Interruption. This is a very good Contrivance to preſerve the Inſtrument from being clogged by the ſwift Motions of the Wheels belonging to the Satellites of *Jupiter* and *Saturn*, when the Motions of the reſt of the Planets are only conſidered.

There is alſo a Braſs Lamp having two Convex Glaſſes, to be put in the Room of the Sun; and alſo a ſmaller Earth and Moon, made ſomewhat in Proportion to their Diſtance from each other, which may be put on at Pleaſure.

The Lamp turns round in the ſame Time with the Earth, and by Means of the Glaſſes caſts a ſtrong Light upon her; and when the ſmaller Earth and Moon are placed on, it will be eaſy to ſhew when either of them may be eclipſed.

Having thus given a brief Deſcription of the outward Part of this Machine, I ſhall next give an Account of the Phænomena explained by it when it is put into Motion.

I. *Of the Motions of the Planets in general.*

Having put on the Handle, puſh in the Pin which is juſt above it, and place a ſmall black Patch (or Bit of Wafer) upon the Middle of the Sun (for Inſtance) right againſt the firſt Degree of ♈; you may alſo place Patches upon *Venus*, *Mars*, and *Jupiter*, right againſt ſome noted Point in the Ecliptic. If you lay a Thread from the Sun to the firſt Degree of ♈, you may ſet a Mark where it interſects the Orbit of each Planet, and that will be a Help to note the Time of their Revolutions.

One entire Turn of the Handle anſwers to the Diurnal Motion of the Earth round her Axis, as may be ſeen by the Motion of the Hour-Index which is placed at the Foot of the Wire on which the Terella is fixed. When the Index has moved the Space of ten Hours, you may obſerve that *Jupiter* has made one Revolution compleat round its Axis; the Handle being turned until the Hour-Index has paſſed over 24 Days 8 Hours, will bring the Patch upon *Venus* to its former Situation with reſpect to the Ecliptic, which ſhews that ♀ has made one entire Revolution round her Axis. *Mars* makes one compleat Revolution round his Axis in 24 Hours and about 40 Minutes. When the Handle is turned $25\frac{1}{2}$ Times round, the Spot upon the Sun will point to the ſame Degree of the Ecliptic, as it did when the Inſtrument was firſt put into Motion. By obſerving the Motions of the Spots upon the Surface of the Sun, and of the Planets in the Heavens, their Diurnal Motion was diſcover'd, after the ſame Manner as we do here obſerve the Motions of their Repreſentatives, by that of the Marks placed upon them.

If while you turn the Handle you obſerve the Planets, you will ſee them perform their Motions in the ſame relative Times as they really do in the Heavens, each making its Period in the Times mentioned in the Tables, *Page* 24, $27\frac{1}{4}$ Turns of the Handle will bring the Moon round the Earth, which is called a *Periodic* Month, and all the while ſhe keeps the ſame Face towards the Earth;

for the Moon's Annual and Diurnal Motion are perform'd both in the ſame Time nearly, ſo that we always ſee the ſame Face or Side of the Moon.

If before the Inſtrument is put into Motion, the Satellites of *Jupiter* and *Saturn* be brought into the ſame right Line from their reſpective Primaries, you'll ſee them as you turn the Handle, immediately diſpers'd from one another, according to their different Celerities. Thus one Turn of the Handle will bring the firſt of *Jupiter*'s Moons about $\frac{4}{7}$ Part round *Jupiter*, while the ſecond has deſcribed but $\frac{2}{7}$ Part, the third but about $\frac{1}{7}$, and the fourth not quite $\frac{1}{16}$ Part, each of its reſpective Orbit. If you turn the Handle until the Hour-Index has moved 18 $\frac{1}{2}$ Hours more, the firſt Satellite will then be brought into its former Poſition, and ſo has made one entire Revolution; the ſecond at the ſame Time will be almoſt diametrically oppoſite to the firſt, and ſo has made a little more than Half of one Revolution; the others will be in different Aſpects, according to the Length of their Periods, as will be plainly exhibited by the Inſtrument. The ſame Obſervations may be made with reſpect to the Satellites of *Saturn*.

The Machine is ſo contrived, that the Handle may be turned either Way; and if before you put it into Motion, you obſerve the Aſpect (or Situation with reſpect to each other) of the Planets, and then turn the Handle round any Number of Times; the ſame Number of Revolutions being made backwards, will bring all the Planets to their former Situations. I ſhall next proceed to Particulars.

Of the Stations and Retrogradations of the Planets.

The Primary Planets, as they all turn round the Sun, at different Diſtances, and in different Times, appear to us from the Earth to have different Motions; as ſometimes they appear to move from Weſt to Eaſt according to the Order of the Signs, which is called their *direct Motion*; then by Degrees they ſlacken their Pace, until at laſt they loſe all their Motion and become *Stationary*, or not to move at all; that is, they appear in the ſame Place with reſpect to the fixed Stars for ſome Time together; after which they again begin to move, but with a contrary Direction, as from Eaſt to Weſt, which is called their *retrograde Motion*; then again they become Stationary, and afterwards reaſſume their direct Motion. The Reaſon of all theſe Appearances is very evidently ſhewn by the *Orrery*.

Stationary.

Retrograde Motion of the Planets.

I. *Of*

Of the Stations, &c. *of the inferior Planets.*

We ſhall inſtance in the Planet *Mercury*, becauſe his Motion round the Sun differs more from the Earth's than that of *Venus* does.

When *Mercury* is in his ſuperior Conjunction (or when he is in a direct Line from the Earth beyond the Sun) faſten a String about the Axis of the Earth, and extend it over *Mercury* to the Ecliptic; then turning the Handle, keep the Thread all the while extended over ☿, and you'll find it move with a direct Motion in the Ecliptic, but continually ſlower, until *Mercury* has the greateſt Elongation from the Earth. Near this Poſition, the Thread for ſome Time will lay over *Mercury* without being mov'd in the Ecliptic, tho' the Earth and *Mercury* both continue their progreſſive Motion in their reſpective Orbits. When *Mercury* has got a little paſt this Place, you'll find the Thread muſt be moved backward in the Ecliptic, beginning firſt with a ſlow Motion, and then faſter by Degrees, until *Mercury* is in his inferior Conjunction, or directly betwixt the Earth and the Sun. Next this Poſition of ☿, his retrograde Motion will be the ſwifteſt; but he ſtill moves the ſame Way, tho' continually ſlower, till he has again come to his greateſt Elongation, where he will appear the ſecond Time to be ſtationary; after which he begins to move forward, and that faſter by Degrees, until he is come to the ſame Poſition with Reſpect to the Earth, that he was in at firſt. The ſame Obſervations may be made relating to the Motions of *Venus*. In like Manner the different Motions obſerved in the ſuperior Planets may be alſo explained by the *Orrery*. If you extend the Thread over *Jupiter*, and proceed after the ſame Manner as before we did in regard to *Mercury*, you'll find that from the Time *Jupiter* is in Conjunction with the Sun, his Motion is direct, but continually ſlower, until the Earth is nearly in a Quadrate Aſpect with *Jupiter*, near which Poſition *Jupiter* ſeems to be ſtationary: After which he begins to move, and ſo continually mends his Pace, until he comes in Oppoſition to the Sun, at which Time his retrograde Motion is ſwifteſt. He ſtill ſeems to go backward, but with a ſlower Pace, till the Earth and he are again in a Quadrate Aſpect, where *Jupiter* ſeems to have loſt all his Motion; after which he again reſumes his direct Motion, and ſo proceeds faſter by Degrees, till the Earth and he are again in Oppoſition to each other.

These different Motions obſerved in the Planets, are eaſily illuſtrated, as followeth: The leſſer Circle round the Sun is the Orbit of

Plate 3. *Fig.* 1.

of *Mercury*, in which he performs his Revolution round the Sun in about three Months, or while the Earth is going thro' $\frac{1}{4}$ Part of her Orbit, or from A to N. The Numbers 1, 2, 3, *&c.* in the Orbit of *Mercury* ſhew the Paces he deſcribes in a Week nearly, and the Diſtances AB, BC, CD, *&c.* in the Earth's Orbit, do likewiſe ſhew her Motion in the ſame Time. The Letters A, B, C, *&c.* in the great Orb, are the Motions of *Mercury* in the Heavens, as they appear from the Earth. Now if the Earth be ſuppoſed in A, and *Mercury* in 12, near his ſuperior Conjunction with the Sun; a Spectator on the Earth will ſee ☿, as if he were in the Point of the Heavens A; and while ☿ is moving from 12 to 1, and from 1 to 2, *&c.* the Earth in the ſame Time alſo moves from A to B, and from B to C, *&c.* All which Time ☿ appears in the Heavens to move in a direct Motion from A to B, and from B to C, *&c.* but gradually ſlower, until he arrives near the Point G; near which Place he appears ſtationary, or to ſtand ſtill; and afterwards (tho' he ſtill continues to move uniformly in his own Orbit, with a progreſſive Motion) yet in the Sphere of the fix'd Stars he'll appear to be retrograde, or to go backwards, as from G to H, from H to I, *&c.* until he has arrived near the Point L, where again he'll appear to be ſtationary; and afterwards to move in a direct Motion from L to M, and from M to N, *&c.*

What has been here ſhewed concerning the Motions of *Mercury*, is alſo to be underſtood of the Motions of *Venus*; but the Conjunctions of *Venus* with the Sun do not happen ſo often as in *Mercury*; for *Venus* moving in a larger Orbit, and much ſlower than *Mercury*, does not ſo often overtake the Earth. But the Retrogradations are much greater in *Venus* than they are in *Mercury*, for the ſame Reaſons.

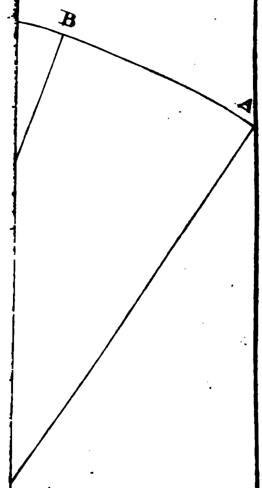
Fig. 2. The innermoſt Circle repreſents the Earth's Orbit, divided into 12 Parts, anſwering to her monthly Motion; the greateſt Circle is the Orbit of *Jupiter*, which he deſcribes in about 12 Years; and therefore the $\frac{1}{12}$ thereof, from A to N, defines his Motion. In one of our Years nearly, and the intermediate Diviſions, A, B, C, *&c.* his monthly Motion. Let us ſuppoſe the Earth to be in the Point of her Orbit 12, and *Jupiter* in A, in his Conjunction with the Sun; it is evident that from the Earth *Jupiter* will be ſeen in the great Orb, or in the Point of the Heavens A, and while the Earth is moving from 12 to 1, 2, *&c.* ♃ alſo moves from A to B, C, *&c.* all which Time he appears in the Heavens to move with a direct Motion from A to B, C, *&c.* until he comes in Oppoſition to the Earth near the Point of the Heavens E, where he appears to be ſtationary; after which ♃ again begins to move (tho' at firſt with a ſlow Pace) from E through F, H, I, to K, where again he appears to ſtand ſtill, but afterwards he reaſſumes his direct Motion from I thro' K, to M, *&c.*

From the Conſtruction of the preceding Figure it appears, that when the ſuperior Planets are in Conjunction with the Sun, their direct Motion is much quicker than at other Times; and that becauſe they really move from Weſt to Eaſt, while the Earth in the oppoſite Part of the Heavens is carried the ſame Way, and round the ſame Center. This Motion afterwards continually ſlackens, until the Planet comes almoſt in Oppoſition to the Sun, when the Line joining the Earth and Planet, will continue for ſome Time nearly parallel to itſelf, and ſo the Planet ſeems from the Earth to ſtand ſtill; after which, it begins to move with a ſlow Motion backward, until it comes into a Quartile Aſpect with the Sun, when again it will appear to be ſtationary for the above Reaſons; after that it will reſume its direct Motion, until it comes into a Conjunction with the Sun, then it will proceed as above explained. Hence it alſo appears, that the Retrogradations of the ſuperior Planets are much ſlower than their direct Motions, and their Continuance much ſhorter; for the Planet, from its laſt Quarter, until it comes in Oppoſition to the Sun, appears to move the ſame Way with the Earth, by whom it is then overtaken: After which it begins to go backwards, but with a ſlow Motion, becauſe the Earth being in the ſame Part of the Heavens, and moving the ſame Way that the Planet really does, the apparent Motion of the Planet backwards muſt thereby be leſſened.

What has been here ſaid concerning the Motions of *Jupiter*, is alſo to be underſtood of *Mars* and *Saturn*. But the Retrogradations of *Saturn* do oftner happen than thoſe of *Jupiter*, becauſe the Earth oftner overtakes *Saturn*; and for the ſame Reaſon, the Regreſſions of *Jupiter* do oftner happen than thoſe of *Mars*. But the Retrogradations of *Mars* are much greater than thoſe of *Jupiter*, whoſe are alſo much greater than thoſe of *Saturn*.

In either of the Satellites of *Jupiter* or *Saturn*, theſe different Appearances in the neighbouring Worlds are much oftner ſeen than we do in the Primary Planets.

We never obſerve theſe different Motions in the Moon, becauſe ſhe turns round the Earth as her Centre; neither do we obſerve them in the Sun, becauſe he is the Centre of the Earth's Motion; whence the apparent Motion of the Sun always appears the ſame Way round the Earth.



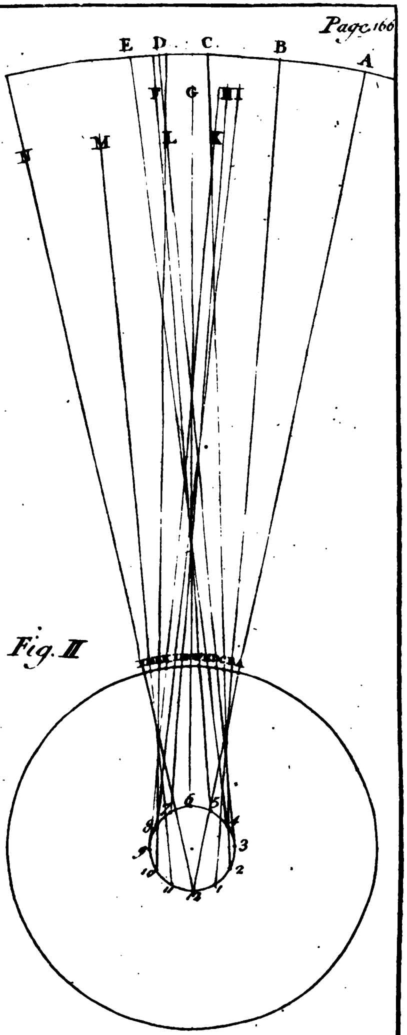


Fig. II

R. Cushee sculp.

Of the Annual and Diurnal Motion of the Earth, and of the Increaſe and Decreaſe of Days and Nights.

The Earth, in her Annual Motion round the Sun, has her Axis always in the ſame Direction, or parallel to itſelf; that is, if a Line be drawn parallel to the Axis, while the Earth is in any Point of her Orbit, the Axis in all other Poſitions of the Earth will be parallel to the ſaid Line. This Paralleliſm of the Axis, and the ſimple Motion of the Earth in the Ecliptic, ſolves all the Phænomena of different Seaſons. Theſe Things are very well illuſtrated by the *Orrery*.

If you put on the Lamp in the Place of the Sun, you will ſee how one Half of our Globe is always illuminated by the Sun, while the other Hemiſphere remains in Darkneſs; how Day and Night are form'd by the Revolution of the Earth round her Axis; for as ſhe turns from Weſt to Eaſt, the Sun appears to move from Eaſt to Weſt. And while the Earth turns in her Orbit, you may obſerve that her Axis always points the ſame Way, and the ſeveral Seaſons of the Year continually change.

To make theſe Things plainer, we will take a View of the Earth in different Parts of her Orbit.

When the Earth is in the firſt Point of *Libra* (which is found by extending a Thread from the Sun, and over the Earth, to the Ecliptic) we have the *Vernal Equinox*, and the Sun at that Time appears in the firſt Point of ♈. In this Poſition of the Earth, the two Poles of the World are in the Line ſeparating Light and Darkneſs; and as the Earth turns round her Axis, juſt one Half of the Equator, and all its Parallels, will be in the Light, and the other Half in the Dark; and therefore the Days and Nights muſt be every where equal.

As the Earth moves along in her Orbit, you'll perceive the North Pole advances by Degrees into the illuminated Hemiſphere, and at the ſame Time the South Pole recedes into Darkneſs; and in all Places to the Northward of the Equator, the Days continually lengthen, while the contrary happens in the Southern Parts, until at length the Earth is arrived in *Capricorn*. In this Poſition of the Earth all the Space included within the Arctic Circle falls wholly within the Light, and all the oppoſite Part, lying within the Antarctic Circle, is quite involved in Darkneſs. In all Places between the Equator and the Arctic Circle, the Days are now at the longeſt, and are gradually longer as the Places are more remote from the Equator. In the Southern Hemiſphere there is a contrary Effect. All the while the Earth is travelling from *Capricorn* towards *Aries*, the North Pole gradually recedes from the Light, and the South Pole approaches nearer to it; the Days in the Northern Hemiſphere gradually decreaſe, and in the Southern Hemiſphere they increaſe in the ſame Proportion, until the Earth be arrived in ♈; then the two Poles of the World lie exactly in the Line ſeparating Light and Darkneſs, and the Days are equal to the Nights in all Places of the World. As the Earth advances towards *Cancer*, the North Pole gradually recedes from the Light, while the Southern one advances into it, at the ſame Rate. In the Northern Hemiſphere the Days decreaſe, and in the Southern one they gradually lengthen, until the Earth being arrived in *Cancer*, the North Frigid Zone is all involved in Darkneſs, and the South Frigid Zone falls intirely within the Light; the Days every where in the Northern Hemiſphere are now at the ſhorteſt, and to the Southward they are at the longeſt. As the Earth moves from hence towards *Libra*, the North Pole gradually approaches the Light, and the other recedes from it; and in all Places to the Northward of the Equator the Days now lengthen, while in the oppoſite Hemiſphere they gradually ſhorten, until the Earth has gotten into ♎; in which Poſition the Days and Nights will again be of equal Length in all Parts of the World.

You might have obſerved that in all Poſitions of the Earth, one Half of the Equator was in the Light, and the other Half in Darkneſs; whence under the Equator, the Days and Nights are always of the ſame Length: And all the while the Earth was going from ♎ towards ♈, the North Pole was conſtantly illuminated, and the South Pole all the while in Darkneſs; and for the other Half Year the contrary. Sometimes there is a Semicircle exactly facing the Sun, fixed over the Middle of the Earth, which may be called the Horizon of the Diſk: This will do inſtead of the Lamp, if that Half of the Earth which is next the Sun be conſider'd, as being the illuminated Hemiſphere, and the other Half, to be that which lies in Darkneſs.

Plate 4. The great Circle ♈, ♉, ♊, *&c.* repreſent the Earth's annual Orbit; and the four leſſer Circles E S Q C, the Ecliptic upon the Surface of the Earth, coinciding with the great Ecliptic in the Heavens. Theſe four leſſer Figures repreſent the Earth in the four Cardinal Points of the Ecliptic, P being the North Pole of the Equator, and *p* the North Pole of the Ecliptic; S P C the Solſtitial Colure, which is always parallel to the great Solſtitial Colure ♋ ⊙ ♑ in the Heavens; E P Q the Equinoctial Colure. The other

Circles paſſing thro' P, are Meridians at two Hours Diſtance from one another; the Semicircle E Æ Q is the Northern Half of the Equator; the parallel Circle touching the Ecliptic in S, is the Tropic of *Cancer*; the dotted Circle the Parallel of *London*, and the ſmall Circle, touching the Pole of the Ecliptic, is the *Arctic Circle*. The ſhaded Part, which is always oppoſite to the Sun, is the obſcure Hemiſphere, or that which lies in Darkneſs; and that which is next the Sun, is the illuminated Hemiſphere.

If we ſuppoſe the Earth in ♎, ſhe'll then ſee the Sun in ♈, (which makes our vernal Equinox) and in this Poſition the Circle, bounding Light and Darkneſs, which here is S C, paſſes thro' the Poles of the World, and biſects all the Parallels of the Equator; and therefore the Diurnal and Nocturnal Arches, or the Lengths of the Days and Nights, are equal in all Places of the World.

But while the Earth, in her annual Courſe, moves through ♏, ♐, to ♑, the Line S C, keeping ſtill parallel to itſelf, or to the Place where it was at firſt, the Pole P will, by this Motion, gradually advance into the illuminated Hemiſphere; and alſo the Diurnal Arches of the Parallels gradually increaſe, and conſequently the Nocturnal ones decreaſe in the ſame Proportion, until the Earth has arrived into ♑; in which Poſition the Pole P, and all the Space within the

Arctic Circle, fall wholly within the illuminated Hemiſphere, and the Diurnal Arches of all the Parallels that are without this Circle, will exceed the Nocturnal Arches more or leſs, as the Places are nearer to, or farther off from it, until the Diſtance from the Pole is as far as the Equator, where both theſe Arches are always equal.

Again, while the Earth is moving from ♑, through ♒, ♓, to ♈, the Pole P begins to incline to the Line, diſtinguiſhing Light and Darkneſs in the ſame Proportion that before it receded from it; and conſequently the Diurnal Arches gradually leſſen, until the Earth has arrived into ♈, where the Pole P will again fall on the Horizon, and ſo cauſe the Days and Nights to be everywhere equal. But when the Earth has paſſed ♈, while ſhe is going thro' ♉ and ♊, *&c.* the Pole P will begin to fall in the obſcure Hemiſphere, and ſo recede gradually from the Light, until the Earth is arrived in ♋; in which Poſition not only the Pole, but all the Space within the Arctic Circle, are, involved in Darkneſs, and the Diurnal Arches of all the Parallels, without the Arctic Circle, are equal to the Nocturnal Arches of the ſame Parallels, when the Earth was in the oppoſite Point ♑; and it is evident that the Days are now at the ſhorteſt, and the Nights the longeſt. But when the Earth has paſt this Point, while ſhe is going

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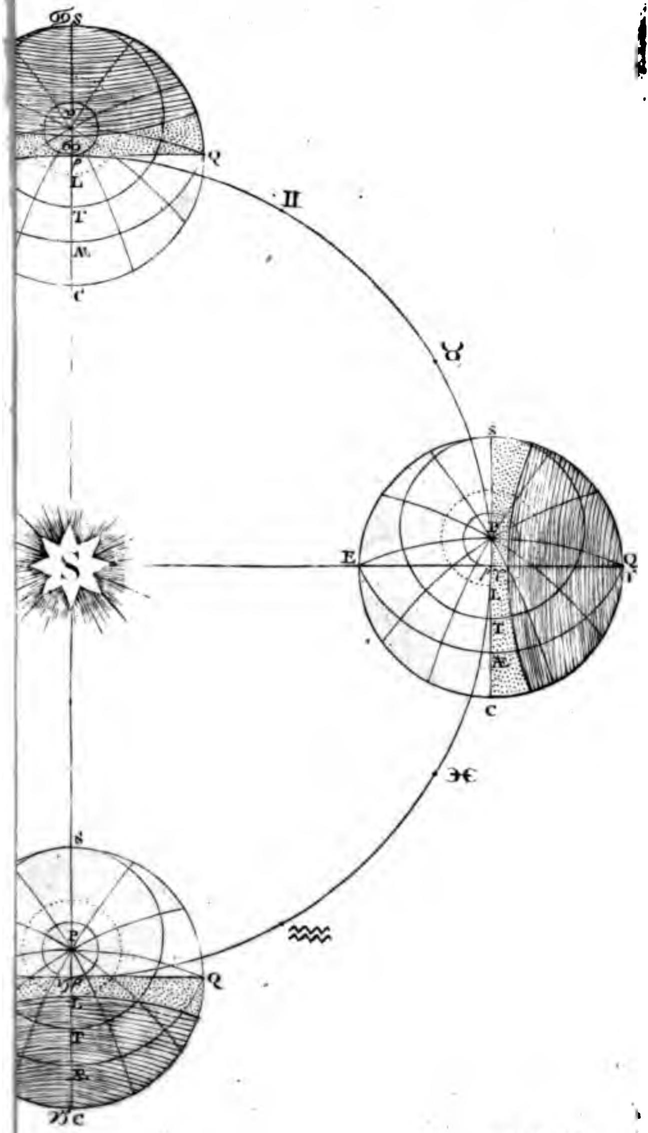


R. Cuſhee ſculp.

through ♌ and ♏, the Pole P will again gradually approach the Light, and ſo the Diurnal Arches of the Parallels gradually lengthen, until the Earth is arrived in ♎; at which Time the Days and Nights will again be equal in all Places of the World, and the Pole itſelf juſt ſee the Sun.

Here we only conſidered the Phænomena belonging to the Northern Parallels; but if the Pole P be made the South Pole, then all the Parallels of Latitude will be Parallels of South Latitude, and the Days every where, in any Poſition of the Earth, will be equal to the Nights of thoſe who lived in the oppoſite Hemiſphere, under the ſame Parallels.

Of the Phaſes of the Moon, and of her Motion in her Orbit.

The Orbit of the Moon makes an Angle with the Plane of the Ecliptic, of above 5¼ Degrees, and cuts it into two Points, diametrically oppoſite (after the ſame Manner as the Equator and the Ecliptic cut each other upon the Globe, in ♈ and ♎) which Points are called the *Nodes*; and a right Line joining theſe Points, and paſſing through the Center of the Earth, is called the *Line of the Nodes*. That Node where the Moon begins to aſcend Northward above the Plane of the Ecliptic, is called the *Aſcending Node*, and the *Head of the Dragon*, and is thus commonly marked ☊. The other Node, from whence the Moon deſcends to the

Nodes.

Line of the Nodes.

Dragon's Head.

Dragon's Tail.

Retrograde Motion of the Nodes.

the Southward of the Ecliptic is called the *Deſcending Node*, and the *Dragon's Tail*, and is mark'd ☋. The Line of the Nodes continually ſhifts itſelf from Eaſt to Weſt, contrary to the Order of the Signs; and with this *Retrograde* Motion, makes one Revolution round the Earth, in the Space of about 19 Years.

Periodical Month.

Synodical Month.

The Moon deſcribes its Orbit round the Earth in the Space of 27 Days and 7 Hours, which Space of Time is called a *Periodical Month*; yet from one Conjunction to the next, the Moon ſpends 29 Days and a Half, which is called a *Synodical Month*; becauſe, while the Moon in her proper *Orbit* finiſhes her Courſe, the Earth advances near a whole Sign in the Ecliptic; which Space the Moon has ſtill to deſcribe, before ſhe will be ſeen in Conjunction with the Sun.

When the Moon is in Conjunction with the Sun, note her Place in the Ecliptic; then turning the Handle, you'll find that 27 Days and 7 Hours will bring the Moon to the ſame Place; and after you have made 2 $\frac{1}{4}$ Revolutions more, the Moon will be exactly betwixt the Sun and the Earth.

Phaſes of the Moon.

The Moon all the while keeps in her Orbit, and ſo the Wire that ſupports her continually riſes or falls in a Socket, as ſhe changes her Latitude; the black Cap ſhifts itſelf, and ſo ſhews the Phaſes of the Moon, according to her Age, or how much of her en-

enlighten'd Part is ſeen from the Earth. In one Synodical Month, the Line of the Nodes moves about 1 $\frac{1}{2}$ Degree from Weſt to Eaſt, and ſo makes one entire Revolution in 19 Years.

Plate 5. *Fig.* 1.

Let A B be an Arch of the Earth's Orbit, and when the Earth is in T, let the Moon be in N, in Conjunction with the Sun in S, while the Moon is deſcribing her Orbit N A F D, the Earth will deſcribe the Arch of her Orbit T *t*; and when the Earth has got into the Point *t*, the Moon will be in the Point of her Orbit *n*, having made one compleat Revolution round the Earth. But the Moon, before ſhe comes in Conjunction with the Sun, muſt again deſcribe the Arch *n o*; which Arch is ſimilar to T *t*, becauſe the Lines F N, *f n*, are parallel; and becauſe, while the Moon deſcribes the Arch *n o*, the Earth advances forward in the Ecliptic; the Arch deſcribed by the Moon, after ſhe has finiſhed her periodical Month, before ſhe makes a Synodical Month, muſt be ſomewhat greater than *n o*. To determine the mean Length of a Synodical Month, find the Diurnal Motion of the Moon (or the Space ſhe deſcribes round the Earth in one Day) and likewiſe the Diurnal Motion of the Earth; then the Difference betwixt theſe two Motions is the apparent Motion of the Moon round the Earth in one Day; then it will be, as this differential Arch is to a whole Circle,

Circle; ſo is one Day to that Space of Time wherein the Moon appears to deſcribe a compleat Circle round the Earth, which is about 29 ½ Days. But this is not always a true *Lunation*, for the Motion of the Moon is ſometimes faſter, and ſometimes ſlower, according to the Poſition of the Earth in her Orbit.

In one Synodical Month the Moon has all Manner of Aſpects with the Sun and Earth, and becauſe ſhe is opaque, that Face of hers will only appear bright which is towards the Sun, while the oppoſite remains in Darkneſs. But the Inhabitants of the Earth can only ſee that Face of the Moon which is turned towards the Earth; and therefore, according to the various Poſitions of the Moon, in Reſpect of the Sun and Earth, we obſerve different Portions of her illuminated Face, and ſo a continual Change in her ‡ *Phaſes*.

Fig. 2. Let S be the Sun, R T V an Arch of the Earth's Orbit, T the Earth, and the Circle A B C D, *&c.* the Moon's Orbit, in which ſhe turns round the Earth in the Space of a Month; and let A, B, C, *&c.* be the Centers of the Moon in different Parts of her Orbit.

---

‡ *Phaſes* of the Moon are thoſe different Appearances we obſerve in her, according to her Poſition in reſpect of the Sun and Earth.

Now if with the Lines S A, S B, *&c.* we join the Centers of the Sun and Moon, and at right Angles to theſe draw the Lines H O; the ſaid Lines H O will be the Circles that ſeparate the illuminated Part of the Moon from the dark and obſcure. Again, if we conceive another Line I L to be drawn at right Angles to the Lines T A, T B, *&c.* paſſing from the Center of the Earth to the Moon, the ſaid Line I L will divide the viſible Hemiſphere of the Moon, or that which is turned toward us, from the inviſible, or that which is turned from us; and this Circle may be called the *Circle of Viſion.*

Full Moon. Now it is manifeſt, that whenever the Moon is in the Poſition A, or in that Point of her Orbit which is oppoſite to the Sun, the Circle of Viſion, and the Circle bounding Light and Darkneſs, do coincide, and all the illuminated Face of the Moon is turned towards the Earth, and is viſible to us; and in this Poſition the *Moon* is ſaid to be *full.* But when the Moon arrives to B, all her illuminated Face is then not towards the Earth, there being a Part of it, H B I, not to be ſeen by us; and then her viſible Face is deficient from a Circle, and appears of a gibbous Form, as in B, *Fig.* 3. Again when ſhe arrives to C, the two forementioned Circles cut each other at right Angles, and then we obſerve a *Half Moon,* as in C, *Half Moon.*

Fig. 3. And again the illuminated Face of the Moon is more and more turned from the Earth, until ſhe comes to the Point E, where the Circle of Viſion, and that bounding Light and Darkneſs, do again coincide. Here the Moon diſappears, the illuminated Part being wholly turned from the Earth; and ſhe is now ſaid to be in *Conjunction* with the *Sun*, becauſe ſhe is in the ſame Direction from the Earth that the Sun is in, which Poſition we call a *New Moon*. *New Moon.* When the Moon is arrived to F, ſhe again reſumes a horned Figure, but her Horns (which before the Change were turned Weſtward) have now changed their Poſition, and look Eaſtward. When ſhe has arrived to a Quadrate Aſpect at G, ſhe'll appear biſſected, like a Half Moon, afterwards ſhe'll ſtill grow bigger, until at laſt ſhe comes to A, where again ſhe'll appear in her full Splendor.

The ſame Appearances which we obſerve in the Moon are likewiſe obſerved by the *Lunarians* in the Earth, our Earth being a Moon to them, as their Moon is to us; and we are obſerved by them to be carried round in the Space of Time that they are really carried round the Earth. But the ſame Phaſes of the Earth and Moon happen when they are in contrary Poſition; for when the Moon is in Conjunction to us, the Earth is then in Oppoſition to the Moon, and the *Lunarians* have then a full Earth, as we in a ſimilar Poſition have a full Moon. When the Moon comes in Oppoſition to the Sun, the Earth, ſeen from the Moon, will appear in Conjunction with her, and in that Poſition the Earth will diſappear; afterwards ſhe'll aſſume a horned Figure, and ſo ſhew the ſame Phaſes to the Inhabitants of the Moon as ſhe does to us.

Of the Eclipſes of the Sun and Moon.

An *Eclipſe* is that Deprivation of Light in a Planet, when another is interpoſed betwixt it and the Sun. Thus, an Eclipſe of the Sun is made by the Interpoſition of the Moon at her Conjunction, and an Eclipſe of the Moon is occaſioned by the Shadow of the Earth falling upon the Moon, when ſhe is in Oppoſition to the Sun. *Eclipſe.*

Let S be the Sun, T the Earth, and ABC its Shadow; now if the Moon, when ſhe is in Oppoſition to the Sun, ſhould come into the conical Space A B C, ſhe'll then be deprived of the Solar Light, and ſo undergo an Eclipſe. *Fig.* 4. *Lunar Eclipſe.*

In the ſame Manner, when the Shadow of the Moon falls upon the Earth (which can never happen but when the Moon is in Conjunction with the Sun) that Part upon which the Shadow falls will be involved in Darkneſs, and the Sun eclipſed. But becauſe the Moon is much leſs than the Earth, the Sha- *Solar Eclipſe.*

dow of the ☽ cannot cover the whole Earth, *Fig.* 5. but only a Part of it. Let S be the Sun, T the Earth, A B C the Moon's Orbit, and L the Moon in Conjunction with the Sun: Here the Shadow of the Moon falls only upon the Part D E of the Earth's Surface, and there only the Sun is entirely hid; but there are other Parts, EF, DG, on each Side of the Shadow, where the Inhabitants are deprived of Part of the Solar Rays, and that more or leſs according to their Diſtance from the Shadow. Thoſe who live at H and I will ſee Half of the Sun eclipſed, but in the Spaces F M, G N, all the Sun's Body will be viſible without any Eclipſe. From the preceding Figure it appears, that an Eclipſe of the Sun does not reach a great Way upon the Superficies of the Earth; but the whole Body of the Moon may ſometimes be involved in the Earth's Shadow.

Although the Moon ſeen from the Earth, and the Earth ſeen from the Moon, are each alternately, once a Month, in Conjunction with the Sun; yet, by Reaſon of the Inclination of the Moon's Orbit to the Ecliptick, the Sun is not eclipſed every New Moon, *Fig.* 6. nor the Moon at every Full. Let T be the Earth, DTE an Arch of the Ecliptic, ALBF the Moon's Orbit, having the Earth T in its Center; and let AGBC be another Circle coinciding with the Ecliptic, and

A,

A, B, the Nodes, or the two Points where the Moon's Orbit and the Ecliptic cut each other; A the aſcending Node, and B the deſcending Node. The Angle G A L equal to G B L is the Inclination of the Moon's Orbit to the Ecliptick, being about $5\frac{1}{4}$ Degrees. Now a Spectator from the Earth at T, will obſerve the Sun to move in the Circle A G B C, and the Moon in her Orbit A L B F; whence it is evident, that the Sun and Moon can never be ſeen in a direct Line from the Center of the Earth, but when the Moon is in one of the Nodes A or B; and then only will the Sun appear centrally eclipſed. But if the Conjunction of the Moon happens when ſhe is any where within the Diſtance A *c* of the Nodes, either North or South, the Sun will be then eclipſed, more or leſs, according to the Diſtance from the Node A, or B. If the Conjunction happens when the Moon is in *b*, the Sun will be then one half eclipſed; and if it happens when ſhe is in *c*, the Moon's Limb will juſt touch the Sun's Diſk, without hiding any Part of it.

The Shadow of the Earth at the Place where the Moon's Orbit interſects it, is three times as large as the Moon's Diameter, as in *Fig*. 4. and therefore it often happens that Eclipſes of the Moon are Total, when they are not Central: And for the ſame Reaſon the Moon may ſometimes be totally eclipſed for three Hours together; whereas Total Eclipſes of the Sun can ſcarcely ever exceed four Minutes.

The Eclipſes of the Sun and Moon are very well explained by the *Orrery*: Thus, having put the Lamp in the Place of the Sun, and the little Earth and the little Moon in their proper Places, inſtead of the larger ones, let the Room wherein the Inſtrument ſtands be darkened; then turning the Handle about, you'll ſee when the Conjunction of the Moon happens. When ſhe is in or near one of the Nodes, her Shadow will fall upon the Earth, and ſo deprive that Part upon which it falls of the Light of the Sun: If the Conjunction happens when the Moon is not near one of the Nodes, the Light of the Lamp will fall upon the Earth, either above or below the Moon, according to her Latitude at that Time. In like Manner, when the full Moon happens near one of the Nodes, the Shadow of the Earth will fall upon the Moon; and if the Moon's Latitude be but ſmall, her whole Face will be involved in Darkneſs. At other Times, when the Full Moon happens when ſhe is not near one of her Nodes, the Shadow of the Earth will paſs either above or below the Moon, and ſo by that Means the Moon will eſcape being eclipſed.

Of the Eclipſes of the Satellites *of* Jupiter.

The apparent Diameters of the Inferior Planets are ſo ſmall, that when they paſs betwixt us and the Sun, they only appear like ſmall Spots upon the Sun's Surface, without depriving us of any ſenſible Quantity of his Light. The Shadow of the Earth likewiſe terminates before it reaches any of the ſuperior Planets, ſo that they are never eclipſed by us; and the Earth, when ſhe is in Conjunction with the Sun, only appears lies a black Spot upon his Surface.

But *Jupiter* and his Moons mutually eclipſe each other, as our Earth and Moon do; as alſo doth *Saturn* and his Moons. The Satellites of *Jupiter* become twice hid from us, in one Circulation round ♃, *viz.* once behind the Body of *Jupiter*, *i. e.* when they are in the right Line joining the Centers of the Earth and ♃; and again they become inviſible when they enter the Shadow of *Jupiter*, which happens when they are at their Full as ſeen from ♃, at which Times they alſo ſuffer Eclipſes; which Eclipſes happen to them after the ſame Manner as they do to our Moon, by the Interpoſition of the Earth betwixt her and the Sun.

Fig. 7.

Let S be the Sun, A B T the Earth's Orbit; and C ♃ D an Arch of *Jupiter*'s Orbit, in which let *Jupiter* be in the Point ♃;

and let CFDH be the Orbit of one of *Jupiter*'s Satellites, which we'll here ſuppoſe to be the fartheſt from him. Theſe Satellites, while they move thro' the inferior Parts of their Orbs, *viz.* from D thro' H, I, to C, ſeem from the Earth and the Sun to have a retrograde Motion; but when they are in the ſuperior Part of their Orbit, they are then ſeen to move from Weſt to Eaſt according to their true Motion. Now while they deſcribe the ſuperior Part of their Orbits, they will be twice hid from the Earth, once in the Shadow of ♃, and once behind his Body. If *Jupiter* be more Weſterly than the Sun, that is, when the Earth is in A, they'll be firſt hid in the Shadow F, and afterwards behind the Body of ♃ in G: But when the Earth is in B, then they are firſt hid behind ♃'s Body in E, and afterwards fall into the Shadow F. While theſe Satellites deſcribe the inferior Parts of their Orbits, they only once diſappear, which may be either in I or H, according to the Poſition of the Earth, in which Places they cannot be diſtinguiſhed from the Body of *Jupiter*.

When the Satellites ſeen from ♃ are in Conjunction with the Sun, their Shadows will then fall upon ♃, and ſome Part of his Body be involved in Darkneſs, to which Part the Sun will be totally eclipſed.

By obſerving the Eclipſes of *Jupiter*'s Satellites, it was firſt diſcover'd that Light is

not

Plate 5

Fig. I

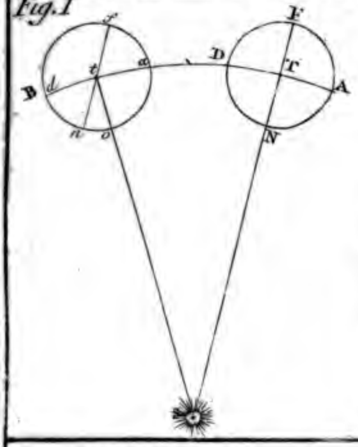


Fig. II

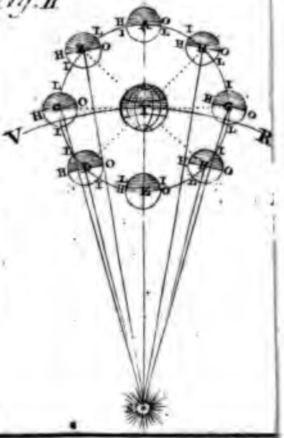


Fig. I

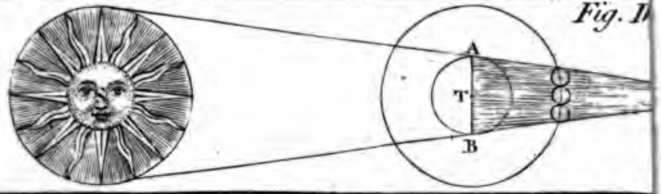


Fig. V

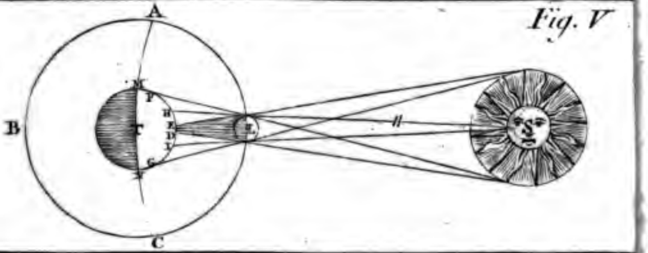
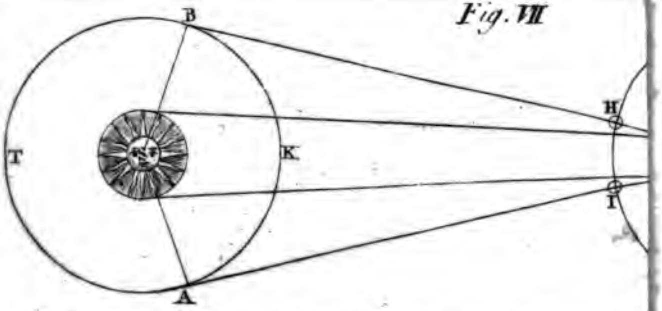


Fig. VII



not propagated inſtantaneouſly, though it moves with an incredible Swiftneſs: For if Light came to us in an Inſtant, an Obſerver in T will ſee an Eclipſe of one of theſe Satellites, at the ſame Time that another in K would. But it has been found by Obſervations, that when the Earth is in K at her neareſt Diſtance from *Jupiter*, theſe Eclipſes happen much ſooner than when ſhe is in T. Now having the Difference of Time betwixt theſe Appearances in K and T, we may find the Length of Time the Light takes in paſſing from K to T, which Space is equal to the Diameter of the Earth's Annual Orb. By theſe Kinds of Obſervations it has been found, that Light reaches from the Sun to us in the Space of eleven Minutes of Time, which is at leaſt at the Rate of 100,000 Miles in a Second.

FINIS.

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